COVER SHEET

SUPPLEMENT TO THE
DRAFT ENVIRONMENTAL IMPACT REPORT/ENVIRONMENTAL IMPACT STATEMENT CADIZ GROUNDWATER STORAGE AND DRY-YEAR SUPPLY PROGRAM
SAN BERNARDINO COUNTY, CALIFORNIA

LEAD AGENCIES:

The Metropolitan Water District
of Southern California
Los Angeles, California

U.S. Department of the Interior
Bureau of Land Management
Riverside, California

COOPERATING AGENCIES:

U.S. Department of the Interior
National Park Service

U.S. Department of the Interior
U.S. Geological Survey

PROPOSED ACTION:

Construction and operation of the Cadiz Groundwater Storage and Dry-Year Supply Program (Cadiz Project) including a groundwater monitoring and management program, amendment of the California Desert Conservation Area (CDCA) Plan for an exception to the utility corridor requirement, and issuance of associated right-of-way grants and permits.

Written information regarding the Supplement to the Draft Environmental Impact Report/Environmental Impact Statement (Supplement) should be submitted to the Metropolitan Water District of Southern California (Metropolitan) or the Bureau of Land Management (BLM) at the addresses below. For further information, contact Metropolitan or BLM at:

Metropolitan Water District
Water Resources Management Group
P.O. Box 54153
Los Angeles, California 90054-0153
Attention:
Mr. Jack Safely (213) 217-6981
Ms. Kathleen Kunysz (213) 217-6272

Bureau of Land Management
California Desert District
6221 Box Springs Boulevard
Riverside, California 92507-0714
Attention:
Mr. James Williams (909) 697-5390

DESIGNATION:

Supplement to the Draft EIR/EIS

ABSTRACT:

In February 1999, Metropolitan issued a Notice of Preparation of an EIR for the Cadiz Project which would be constructed and operated by Metropolitan in the Cadiz and Fenner Valleys of the eastern Mojave Desert, San Bernardino County, California. The BLM determined that an EIS would be required as the proposed action includes an amendment of the CDCA Plan for an exception to the utility corridor requirement and right-of-way easements across federal lands. The BLM issued a Notice of Intent to Prepare an EIS for the proposed action in March 1999. In May 1999, the BLM issued a Notice of Public Meeting and extension of the scoping comment period. The Draft EIR/EIS was published in November 1999 with a public review period from November 26, 1999 through February 22, 2000. The public review period was subsequently extended through March 8, 2000.

Because numerous comments raised questions regarding groundwater management issues, this Supplement has been prepared to provide additional information and to present the Groundwater Monitoring and Management Plan (Management Plan) that has been incorporated into the proposed project. The Management Plan would govern the water storage and extraction operations in the affected groundwater basins, including the amount of indigenous groundwater that may be extracted over the 50-year operational life of the proposed project. In accordance with the California Environmental Quality Act and the National Environmental Policy Act, Metropolitan and the BLM have jointly prepared the Supplement, with the National Park Service and U.S. Geological Survey as cooperating agencies.

The Cadiz Project is proposed by Metropolitan who is acting in partnership with the private company Cadiz Inc. The project would involve construction and operation of a 35-mile pipeline for conveying water between the Iron Mountain Pumping Plant on the Colorado River Aqueduct and the Cadiz/Fenner area, a Cadiz Pumping Plant at Metropolitan's existing Iron Mountain Pumping Plant facility, 390 acres of spreading basins for percolation of Colorado River water into the groundwater basin in the Cadiz/Fenner area, a wellfield for extracting stored Colorado River water and indigenous groundwater, and associated power poles and lines along the conveyance pipeline and in the wellfield.

This Supplement is being distributed for a 45-day review and comment period (October 20, 2000 to December 4, 2000). Written comments regarding the Supplement should be submitted to Metropolitan or BLM at the above addresses prior to the close of the comment period. The Supplement is also available for review on request at the Metropolitan and BLM offices and at the following public libraries:

- Metropolitan Water District
  700 North Alameda Street
  Los Angeles, California 90012

- Bureau of Land Management
  6221 Box Springs Boulevard
  Riverside, California 92507

- Bureau of Land Management
  101 West Spikes Road
  Needles, California 92363

- Norman Feldheym
  Central Library
  555 West 6th Street
  San Bernardino, California 92410

- Needles Branch Library
  1111 Bailey Avenue
  Needles, California 92363

- Twentynine Palms Branch Library
  6078 Adobe Road
  Twentynine Palms, California 92277

- Barstow Branch Library
  304 East Buena Vista Street
  Barstow, California 92311

This Supplement has been approved for public distribution.

OCT 12 [illegible]

Date

for Tim Salt
District Manager
California Desert District
U.S. Bureau of Land Management

OCT 12 [illegible]

Date

Stephen N. Arakawa
Manager, Water Resources Management Group
Metropolitan Water District of Southern California

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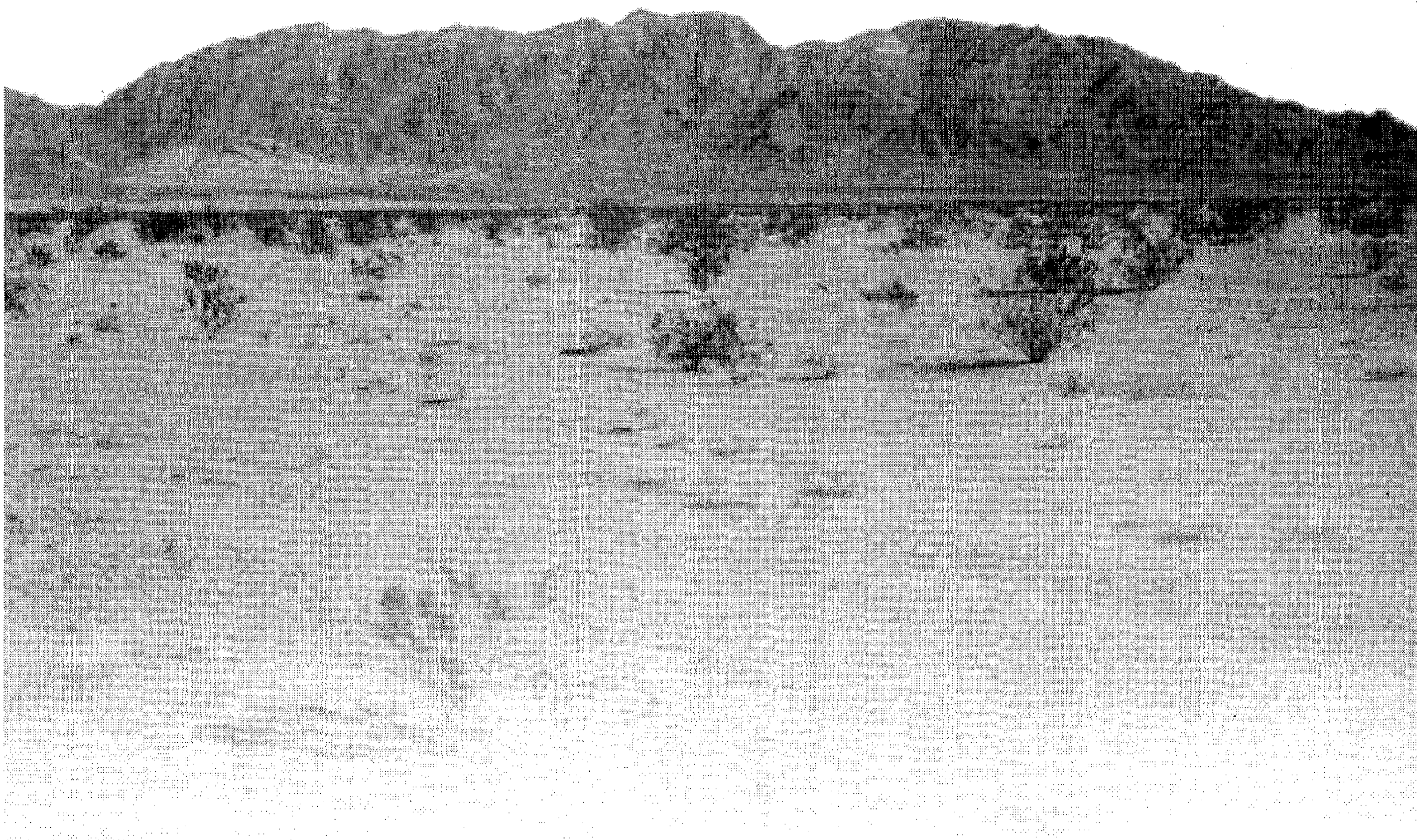


SECTION 1.0

SECTION 1.0
BACKGROUND

1.1 INTRODUCTION

The Metropolitan Water District of Southern California (Metropolitan) and the United States Department of the Interior, Bureau of Land Management (BLM) are jointly evaluating the implementation of the Cadiz Groundwater Storage and Dry-Year Supply Program (Cadiz Project) as a means to enhance management of Metropolitan's water supplies through a cost-effective groundwater storage and transfer program. Metropolitan is partnering with Cadiz Inc. to propose the Cadiz Project. With this project, Metropolitan proposes to utilize the groundwater basins underlying a portion of the Cadiz and Fenner Valleys to store Colorado River water imported from the Colorado River Aqueduct (CRA) during periods of excess supply. When needed, as in dry years, the stored water and indigenous groundwater would be extracted with wells and returned to the CRA for use within Metropolitan's service area. All Cadiz Project operations, including extraction of groundwater, would be governed by and subject to the provisions of the Groundwater Monitoring and Management Plan (Management Plan) presented in Section 3.0 of this Supplement to the Draft Environmental Impact Report/ Environmental Impact Statement (EIR/EIS) (SCH #99021039). This Management Plan would govern all water storage and extraction. It was designed to ensure there would be no significant adverse impacts resulting from project operations.

Facilities necessary for implementation of the Cadiz Project include a 35-mile-long conveyance facility extending from the CRA to the Fenner Gap, a pumping plant to pump water from the CRA through the conveyance facility to the project spreading basins, an above-ground electrical distribution system paralleling the conveyance facility to and within the proposed wellfield, 390 acres of spreading basins and approximately 30 wells in the vicinity of the Fenner Gap, and appurtenant facilities. Groundwater and air quality monitoring facilities are also proposed. A total of 24 different water and air monitoring features have been identified for assessing potential impacts to Critical Resources. Examples of these features include observation wells, land surface surveillance, air quality monitoring instrumentation, weather and meteorological stations.

Metropolitan and BLM are the State and federal lead agencies for preparation of the EIR and the EIS pursuant to the California Environmental Quality Act (CEQA) and the National Environmental Policy Act (NEPA), respectively. The project spreading basins and wellfield would be located on Cadiz Inc. landholdings. Because the conveyance pipeline and electrical distribution system would cross federal lands administered by the BLM, the BLM must consider whether to: 1) amend the California Desert Conservation Area Plan for an exception to the utility corridor requirement; 2) grant rights-of-way to Metropolitan for construction and operation of the project; and 3) potentially grant rights-of-way for areas where water is stored under federal land. The environmental impacts of any such right-of-way have been addressed in this document. Accordingly, in the event it is determined that a right-of-way (for areas where water is stored) is to be granted, such action would not be subject to further environmental evaluation. Metropolitan is a California public agency and must comply with CEQA in the review and decision-making process regarding approval of the Cadiz Project.

The BLM and Metropolitan published the Draft EIR/EIS for the Cadiz Groundwater Storage and Dry-Year Supply Program on November 26, 1999, for a 90-day public review and comment period. Public review and comment was extended for an additional two-week period that ended on March 8, 2000. Public meetings were held in the communities of Cadiz, Twentynine Palms, and Needles on December 15 and 16, 1999, to present information on the Cadiz Project, respond to questions, and receive oral comments.

A number of the comments received on the Draft EIR/EIS raised concerns regarding the proposed Cadiz Project operations related to potential impacts to springs, the Cadiz and Fenner groundwater basins, adjacent groundwater basins, and the potential for increased dust mobilization from Bristol and Cadiz dry lake beds. Notable among these comments was a February 23, 2000 memorandum prepared by the U.S. Geological Survey (USGS) for the BLM and appended to the National Park Service (NPS) letter of comment on the Draft EIR/EIS. This memorandum raised a number of concerns, including the amount of natural recharge to the project area, and is available upon request. Although Metropolitan believes that natural recharge is higher than stated in this memorandum, Metropolitan and BLM convened discussions among experts to determine if the technical disagreements could be resolved. Participating in these discussions were Metropolitan, BLM, NPS, USGS, Cadiz Inc. and the County of San Bernardino. While there remains disagreement among experts regarding the amount of natural recharge to the project area, the parties agreed that the overriding objective is to ensure the protection of environmental resources, and that this objective would best be accomplished through the development and implementation of the Management Plan. Critical Resources identified and protected by the provisions of the Management Plan are the springs in the Mojave National Preserve and BLM-managed lands, the aquifer system, the brine resources of Bristol and Cadiz dry lakes, and air quality (related to dust mobilization at Bristol and Cadiz dry lakes).

Preparation of a Groundwater Monitoring and Management Plan was identified as mitigation measure WR-1 in the Draft EIR/EIS, and it was intended that such a Management Plan would be presented in the Final EIR/EIS. In response to comments received on the Draft EIR/EIS, this Supplement to the Draft EIR/EIS (Supplement) is being circulated to provide the public with the opportunity to review and comment on clarifications to Cadiz Project water resources information including the Management Plan. The Management Plan has been prepared by the BLM, NPS, USGS, Metropolitan, the County of San Bernardino (County), and Cadiz Inc.

The NPS and USGS became cooperating agencies pursuant to NEPA for purposes of preparation of this Supplement to the Draft EIR/EIS and the Final EIR/EIS. As a cooperating agency, the role of the USGS is limited to providing scientific and technical support and advice to the BLM and NPS on the design of the Management Plan. As the Department of the Interior lead agency, the BLM is responsible for all final decisions related to the enforcement of the terms and conditions of any right-of-way grant(s) it issues. Further, the Management Plan is presented in Section 3.0 of this Supplement and has been incorporated into the Cadiz Project proposed action.

Currently within the project area, Cadiz Inc. uses 5,000 to 6,000 acre-feet of groundwater per year to irrigate approximately 1,600 acres of permanent crops with the potential to expand its agricultural operations up to 9,600 acres (FEIR SCH #89020203) (URS Consultants, Inc. 1993 a, b). As a component of the FEIR, the County prescribed a groundwater monitoring plan to monitor the impacts of agricultural groundwater withdrawals on environmental resources. The Cadiz agricultural groundwater monitoring plan would be superseded by this Management Plan to monitor the environmental effects of both agricultural and Cadiz Project withdrawals.

The Management Plan defines Critical Resources and includes water monitoring and air monitoring facilities and strategies related to the dry lake beds, conceptual locations of the monitoring facilities, monitoring procedures, requirements for regular reporting, specific trigger levels for action, specified responses if the trigger levels are reached, a process for a scientific review team to develop groundwater management findings and recommendations, and establishment of a groundwater basin management group. Field data collected over the term of the Cadiz Project would be used to refine models of the geohydrologic system in the Cadiz and Fenner watersheds and to make predictions regarding its behavior. Data and Management Plan findings would be made available to the public.

One of the key objectives of this Management Plan is to provide "early warning" of potential adverse impacts to Critical Resources that could result from Cadiz Project operations. With such early warning, adverse impacts would be prevented by implementation of suitable mitigation measures or corrective actions. With implementation of the Management Plan, adverse impacts to Critical Resources would be avoided regardless of the amount of natural recharge to the project area. The Management Plan would be implemented under the guidance of a Technical Review Team (TRT) and Basin Management Group (BMG) comprised of representatives from federal, state and local government, and Cadiz Inc. The BLM would retain ultimate control over the enforcement of the terms and conditions of any right-of-way grant(s) it issues.

1.2 PURPOSE, SCOPE AND ORGANIZATION OF SUPPLEMENT

1.2.1 PURPOSE AND SCOPE

The purpose of the Supplement is to clarify and address water resource-related questions raised during the comment period on the Draft EIR/EIS and to circulate the Management Plan for public review and comment. Therefore, this Supplement reviews the potential effects of the proposed Cadiz Project groundwater operations (storage, extraction, and transfer) on the Cadiz and Fenner groundwater basins, adjacent groundwater basins, water quality, surface water resources such as springs, and the Cadiz and Bristol dry lake beds. Related potential impacts include geological issues such as subsidence and hydrocompaction and air quality impacts should the dry lake beds be altered by the Cadiz Project to mobilize fine dust or particulate matter known as PM_{10}. Impacts to the water resources and related considerations are re-evaluated in light of the development of the Management Plan and its incorporation into the proposed action. Additionally, cumulative effects of this and other projects on the subject water resources are reevaluated. Because this Supplement is focused on water resources and related air quality issues, it does not address other resources that could be affected by the project. The Draft EIR/EIS addressed issues such as potential effects on endangered species, wildlife habitat, and cultural resources; these issues are not revisited in this Supplement. Should this Supplement contain language that conflicts or is inconsistent with the Draft EIR/EIS, the language in this Supplement shall prevail.

The technical team assembled to develop the Management Plan has conceptually located the monitoring facilities proposed in the Management Plan. As the Management Plan is implemented, the technical team would define specific locations for all monitoring facilities. This Supplement provides a qualitative discussion of the types of impacts that could occur as a result of implementation of the Management Plan. Such impacts would be related to the drilling of new monitoring wells at specific locations, utilization of existing wells for monitoring purposes, placement of other types of monitoring equipment within the potentially affected region, and visiting these facilities in order to collect data and to provide for maintenance of them. Prior to construction of facilities necessary to implement the Management Plan, BLM and Metropolitan would prepare appropriate environmental documentation and would coordinate with agencies having jurisdiction over resources that could be affected by implementation of the Management Plan.

A 45-day comment period, beginning on October 20, 2000 and concluding on December 4, 2000 has been established for submittal of comments on this Supplement. Comments should be submitted to either of the following individuals during this time period:

Mr. Jack Safely (213) 217-6981
Metropolitan Water District of
Southern California
P.O. Box 54153
Los Angeles, California 90054

Mr. James Williams (909) 697-5390
U.S. Bureau of Land Management
6221 Box Springs Boulevard
Riverside, California 92507

1.2.2 ORGANIZATION OF SUPPLEMENT

The Supplement is organized in 10 sections. Section 1.0, "Background," describes the history and process of the environmental review of the Cadiz Project, the purpose and need for the project, and a summary of the proposed action.

Section 2.0, "Water Resources Affected Environment," discusses the environmental background important to understanding the Cadiz Project in general and the Management Plan in particular. This section describes the physiography and topography, geology, climate, hydrology and phreatophyte vegetation in and adjacent to the project area.

Section 3.0 presents the Groundwater Monitoring and Management Plan. The Management Plan would govern all water storage and extraction and is designed to ensure there would be no adverse impacts to Critical Resources resulting from Cadiz Project operations. It would establish monitoring facilities and processes that would provide an "early warning" of potential impacts and would require timely implementation of corrective measures to prevent such impacts from occurring.

Sections 4.0 and 5.0, "Thresholds of Significance" and "Methodology," respectively, are provided in response to requirements of CEQA to disclose the bases for evaluation of potential impacts in the Supplement. Section 6.0, "Water Resources Impacts and Mitigation" discusses the potential impacts identified in Section 3.0 in greater depth. Potential impacts and the methods for monitoring and mitigating potential impacts are also presented in Section 6.0.

In Section 7.0, "Cumulative Effects to Water Resources," those impacts identified in Section 6.0 are considered together with other past, present, and reasonably foreseeable projects in the vicinity of the project area to determine whether the cumulative impact of the Cadiz Project is significant. Section 7.0 considers impacts to water resources considering all uses of water in the area.

Section 8.0 provides the index for this Supplement and the Draft EIR/EIS, Section 9.0 lists the preparers of the Supplement, and Section 10.0 lists the references used.

1.3 OVERVIEW DISCUSSION OF REVIEW PROCESS

As discussed above, this Supplement has been prepared to generally respond to a number of comments that were raised regarding potential water resources and related air quality impacts of the Cadiz Project and to circulate the Management Plan for public review and comment.

All other comments on the Draft EIR/EIS not addressed in the Supplement will be addressed in the Final EIR/EIS in a comment/response format, and changes will be made to the document as appropriate. Comments received on this Supplement will also be addressed in the Final EIR/EIS in the comment/response format. The initial Draft EIR/EIS and the Supplement together comprise the complete Draft EIR/EIS. The Final EIR/EIS will address the complete Draft EIR/EIS.

1.3.1 FINAL EIR/EIS

The Final EIR/EIS comment/response discussion will be published for a 30-day public review prior to any federal action to approve the Cadiz Project. Any comments received on the Final EIR/EIS would be considered by BLM in the preparation of its Records of Decision (see discussion below). A comprehensive Mitigation Monitoring Plan that addresses all Cadiz Project mitigation measures will also be prepared for adoption by decision-makers at the time of consideration of the Final EIR/EIS and approval of the project.

1.3.1.1 Summary of Response to Comments Process

The Draft EIR/EIS (consisting of the initial Draft and the Supplement) will be finalized in the Final EIR/EIS by responding to comments and modifying the document as appropriate. All letters of comment received and testimony presented at the public meetings will be published. Substantive comments within these letters will be bracketed and numbered. Responses will reference the numbered comments. Similar comments may be addressed in a common response. Where comments were addressed in the Supplement, such indication will be made. In all cases, where the response indicates a modification or clarification of the EIR/EIS, such modification or clarification will be noted in the response.

1.3.1.2 Summary of Mitigation Monitoring Plan Process

A comprehensive Mitigation Monitoring Plan will accompany the Final EIR/EIS for review and consideration by decision-makers at BLM and Metropolitan who must determine whether or not or how to approve the project. This Mitigation Monitoring Plan will consolidate all mitigation measures for all potentially affected resources (e.g. biological and cultural resources) identified throughout the EIR/EIS including measures incorporated into the project design to avoid impacts, and will identify the potential impact addressed by each measure, the monitoring period (design, pre-construction, construction, post-construction), the monitoring agency/responsible party, any outside agency coordination required, and any necessary reporting. The Groundwater Monitoring and Management Plan comprises a portion of the comprehensive Mitigation Monitoring Plan. The purpose of the Mitigation Monitoring Plan is to ensure that all mitigation commitments are implemented.

1.3.2 DECISION DOCUMENTS

BLM and Metropolitan must make a final determination regarding the Cadiz Project in accordance with NEPA and CEQA. BLM must determine whether to: 1) amend the California Desert Conservation Area Plan for an exception to the utility corridor requirement, 2) grant rights-of-way to Metropolitan for construction and operation of the Cadiz Project, and 3) potentially grant a right-of-way for areas where water is stored under federal land. The proposed plan amendment is issued for a 30-day protest period prior to any decision being made by BLM. The protest period would run concurrently with the 30-day review period on the Final EIR/EIS. Metropolitan's Board of Directors must determine whether to approve the project based on the information contained in the Final EIR/EIS, and adopt the Mitigation Monitoring Plan if approving the project.

1.3.2.1 Records of Decision

If the BLM determines to approve the plan amendment, right-of-way grant, and potentially grant a right-of-way for areas where water is stored under federal land for the Cadiz Project, it would prepare a ROD for each of the decisions. The Notice of Availability of a ROD would be published in the Federal Register following each of the decisions by BLM.

1.3.2.2 Notice of Determination

If the Metropolitan Board of Directors determines to approve the Cadiz Project, a Notice of Determination would be posted with the San Bernardino County Clerk of the Board of Supervisors and with the State Clearinghouse, California Office of Planning and Research.

1.4 PURPOSE AND NEED FOR THE PROJECT

Metropolitan's mission is to provide its service area with adequate and reliable supplies of high quality water. In fulfilling this mission, Metropolitan has analyzed a wide variety of water resources and management tools. One of Metropolitan's primary resources is water from the Colorado River brought to Southern California through the CRA. Metropolitan has established a goal of maximizing the efficiency of the CRA and use of Colorado River water. The Cadiz Project has been proposed to contribute to achievement of this goal.

Uncertainties regarding the availability of water supplies to serve Southern California's urban economy have traditionally focused on hydrologic shortages. Water has been stored for use during dry seasons and for periods of drought. Political and environmental regulatory issues have added new sources of uncertainty. Concerns of other Lower Colorado River Basin states with California's continued reliance on unused Colorado River waters has spurred the U.S. Department of Interior to require California to develop a plan to live within its Colorado River water apportionment. As a result, Metropolitan continues to diversify its sources of supply and to seek new and creative means to make more efficient use of available supplies. Metropolitan has a goal of maintaining a full CRA, and programs such as the Cadiz Project are essential to addressing the need for diversification of water supplies from the Colorado River. The three main goals of the Cadiz Project are to provide: 1) storage of Colorado River water and withdrawal of stored water, 2) transfer (extraction and delivery) of indigenous groundwater for use within Metropolitan's service area; and 3) management of all storage and transfer operations (including the extraction of indigenous groundwater) to ensure the protection of Critical Resources.

The following subsections summarize Metropolitan's integrated water resources planning and California's Colorado River water use planning, and are included to clarify the review process for identifying and considering possible options for maintaining full deliveries from the CRA and the proposed operation of the Cadiz Project.

1.4.1 METROPOLITAN'S INTEGRATED RESOURCES PLANNING

In 1996, Metropolitan prepared an Integrated Resources Plan (IRP) which is a planning tool that outlines strategies to secure and manage water resources to meet Metropolitan's service area needs. Metropolitan has developed projects, programs and policies that are guided by the set of IRP recommendations.

The IRP determined that a mix of water resources and management tools is needed to provide reliable water supplies of acceptable quality and affordability. In order to develop and maintain such a mix, it is necessary to implement a wide variety of water programs and management tools. The need for continued full CRA deliveries is predicated on the simultaneous implementation of a high level of water conservation, recycling and reclamation. Without implementation of these water efficiency measures, shortages would not be averted even with continued full CRA deliveries. Further, because a number of variables affect availability of each water supply, large or small, only a balanced mix of water resources can provide sufficient flexibility to provide a reasonable assurance of reliability. The Cadiz Project is one option to address the IRP recommendation for a full CRA. Other parallel efforts have also been implemented or are under review to develop the mix of management tools and resources needed to provide a reliable water supply.

In developing recommendations for a preferred mix of water resources to meet the needs of the service area, the primary objectives identified by the IRP are to:

- Ensure reliability of water supplies;

- Ensure affordability of reliable water supplies;
- Ensure water quality with particular attention to salinity in order to facilitate implementation of cost-effective local groundwater conjunctive use storage and water recycling projects;
- Maintain diversity of water resources in order to minimize the overall risks associated with the long-term water resources plan;
- Ensure flexibility to minimize the risk of stranded investments (costs which are incurred for facilities that are ultimately not needed due to changes in demands); and
- Incorporate institutional/environmental constraints in the development of a resource strategy; although imported supplies may appear to be lower in costs than some local resources, the success of imported resources development may be difficult to achieve without a strong commitment to utilize feasible local resources (conservation, water recycling, and groundwater) first.

The IRP made the following recommendations to guide Metropolitan's future water resources planning:

- Fully implement water conservation best management practices (BMPs) to achieve significant reductions in regional water demands;
- Make full use of economically feasible local water supplies, such as groundwater, reclaimed water, and desalinated water;
- Maximize the use of deliveries from the Colorado River Aqueduct;
- Maintain and fully utilize dependable flows in the State Water Project;
- Optimize the use of Central Valley water transfers; and
- Maximize storage within Metropolitan's service area.

1.4.2 RELATIONSHIP TO THE CALIFORNIA COLORADO RIVER WATER USE PLAN

In order to maximize the efficiency of the CRA and use of Colorado River water, Metropolitan and other California water agencies developed California's Colorado River Water Use Plan (California Plan). The proposed Cadiz Project contributes to Metropolitan's ability to meet the objectives of the California Plan as well as addresses the recommendations of Metropolitan's IRP. California is one of three states which are collectively authorized to divert and use 7.5 million acre-feet/year of water (MAF) from the Lower Basin of the Colorado River system pursuant to the Colorado River Compact of 1922 and the Boulder Canyon Project Act of 1929. The United States Supreme Court has ruled that California is limited to 4.4 MAF of this apportionment, plus fifty percent of any declared surplus (determined by the U. S. Secretary of the Interior). For the past several decades, California has exceeded its annual 4.4 MAF diversions from the Colorado River through use of surplus water or the unused water apportioned to Arizona and Nevada. California's annual use of Colorado River water has varied over this period from 4.5 MAF to 5.2 MAF. Arizona is now fully using its annual apportionment and Nevada will soon reach full use of its annual apportionment. In years this occurs, California will be unable to rely on unused water apportioned to other States, and will be forced to rely solely on surplus water to exceed the 4.4 MAF limitation. In anticipation of potential reductions in Colorado River water supplies, the Colorado

River Board of the State of California began development of the California Plan. A draft of the California Plan was issued by the Colorado River Board for public review in May 2000. The California Plan is scheduled to be finalized in January 2001 following its public review and execution of supporting agreements.

An important goal of the California Plan is to establish baselines for water usage in agricultural areas, which will encourage conservation programs and voluntary water transfers from agricultural to urban agencies. Projects which would conserve agricultural water would allow maintenance of current agricultural production levels with less water. The voluntary transfer of conserved agricultural water to Metropolitan's service area will enable Metropolitan to keep the CRA operating at up to full capacity.

1.4.3 SELECTION OF THE CADIZ PROJECT FOR DETAILED REVIEW

Metropolitan's integrated resource planning concluded that maintaining full CRA deliveries would be important to maintaining cost-effective, reliable supplies to meet the demands of its Southern California service area through 2020. As discussed above, Metropolitan has relied on available unused water and surplus Colorado River water to maintain full deliveries from the CRA. Because Arizona and Nevada are increasing utilization of their apportionments on the Colorado River, the availability of unused Colorado River water for California will decline. As a result, Metropolitan has reviewed the feasibility of other options that have the potential to contribute to maintenance of CRA delivery levels through 2020. The options found feasible at this time have been integrated into the California Plan as discussed above.

Section 3.0 of the November 1999 Draft EIS/EIR discusses 13 potential options that have been evaluated for their potential to contribute to the maintenance of full deliveries by the CRA. This study concluded that three projects appeared feasible and recommended further evaluation of these potential projects: a storage program in the Hayfield/Chuckwalla groundwater basin; a storage program in the Coachella Valley; and a storage and indigenous groundwater extraction and transfer project in the Cadiz Project area. The status of these potential projects is as follows: a pilot project for the Hayfield/Chuckwalla program has been successfully implemented; a detailed feasibility study of the groundwater basins in the upper and lower Coachella Valleys is near completion; and the Cadiz Project is undergoing environmental review and is discussed herein. The Cadiz Project was one of three of these projects found to be potentially feasible and warranting further review. The Cadiz Project would assist Metropolitan in meeting its objective of maximizing the use of deliveries from the CRA, as well as adding to a mix of resources that will help achieve the overall goal of providing reliable water supplies of acceptable quality and affordability, particularly during periods of drought.

1.4.4 SUMMARY OF THE PROPOSED CADIZ PROJECT

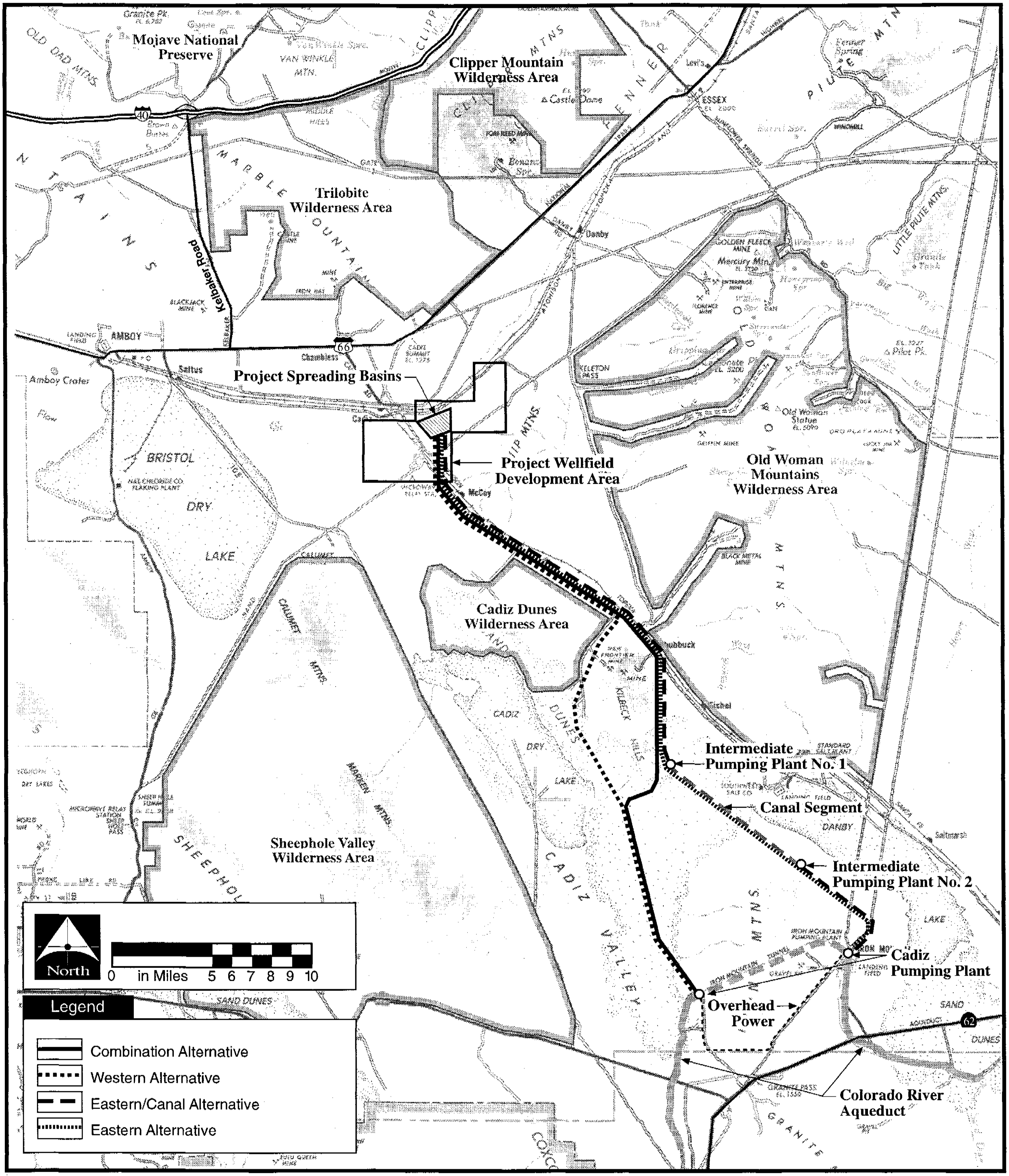
The Cadiz Project would contribute to Metropolitan's continued ability to operate a full CRA to meet the water supply needs of nearly 17 million people within its Southern California service area. It would enable Metropolitan to store available surplus or unused Colorado River water in the groundwater basin underlying the Cadiz Valley for later dry-year use; to pump the quantity of stored Colorado River water and convey it to the CRA during dry years on the Colorado River; and to transfer a portion of the indigenous groundwater from the Cadiz Valley groundwater basin to the CRA subject to the requirements of the Management Plan. All Cadiz Project groundwater operations, including the amount of indigenous groundwater extracted, would be governed by and subject to the provisions of the Management Plan presented in Section 3.0 of this Supplement. The Management Plan would govern all water storage and extraction of Cadiz Project operations.

The project would have three phases. A Pre-Operational phase of 15 to 24 months would begin upon project approval and end upon completion of facilities necessary to store water in the project area. There would be an Operational phase of 50 years, and a Post-Operational phase of 10 years or greater. During the initial years of the Operational phase, it is anticipated that Metropolitan would store significant amounts of Colorado River water.

Facilities proposed to implement the Cadiz Project include a conveyance facility (buried pipeline or canal) extending approximately 35 miles from the CRA to the Fenner Gap in Cadiz Valley and a pumping plant to pump water from the CRA through the conveyance facility to the project spreading basins. A set of earthen basins covering 390 acres would be constructed in the Fenner Gap to receive Colorado River water and percolate it into the underlying groundwater basin for storage and later extraction. A wellfield would also be constructed in the vicinity of the Fenner Gap to extract the stored Colorado River water and also to extract indigenous groundwater. Above-ground power distribution facilities would parallel the conveyance facility from the CRA and would be linked to approximately 30 wells within the wellfield. In addition, a total of 24 different monitoring features have been identified for assessing potential impacts to Critical Resources as specified in the Management Plan, Section 3.0.

When available, Colorado River water would be diverted from the CRA to the conveyance facility and to the spreading basins for percolation to the groundwater basin. The project would have capability to recharge or extract up to 150,000 acre-feet of water in a given year, store up to 1.0 million acre-feet of Colorado River water at any one time, and transfer (extraction and delivery) indigenous groundwater over the 50-year operational life of the project. Cadiz Project storage and extraction, including year-to-year storage of Colorado River water and extraction of stored and indigenous groundwater, would be governed by and subject to the Management Plan presented in Section 3.0 of this Supplement. The actual quantity of water to be stored and transferred is not known at this time. The storage of Colorado River water and the extraction of indigenous groundwater that would be transferred are conditioned by the requirements of the Management Plan, and therefore would be quantified during its implementation. Further, all existing and future use of groundwater for any on-site agricultural operations by Cadiz Inc. would also be governed by this Management Plan through completion of Post-Operational phase of the Cadiz Project.

For a detailed discussion of the proposed facilities and alternative project alignments please refer to Section 4.0 of the November 1999 Draft EIR/EIS. Figure 1-1 illustrates the alternative facility configurations for the project.



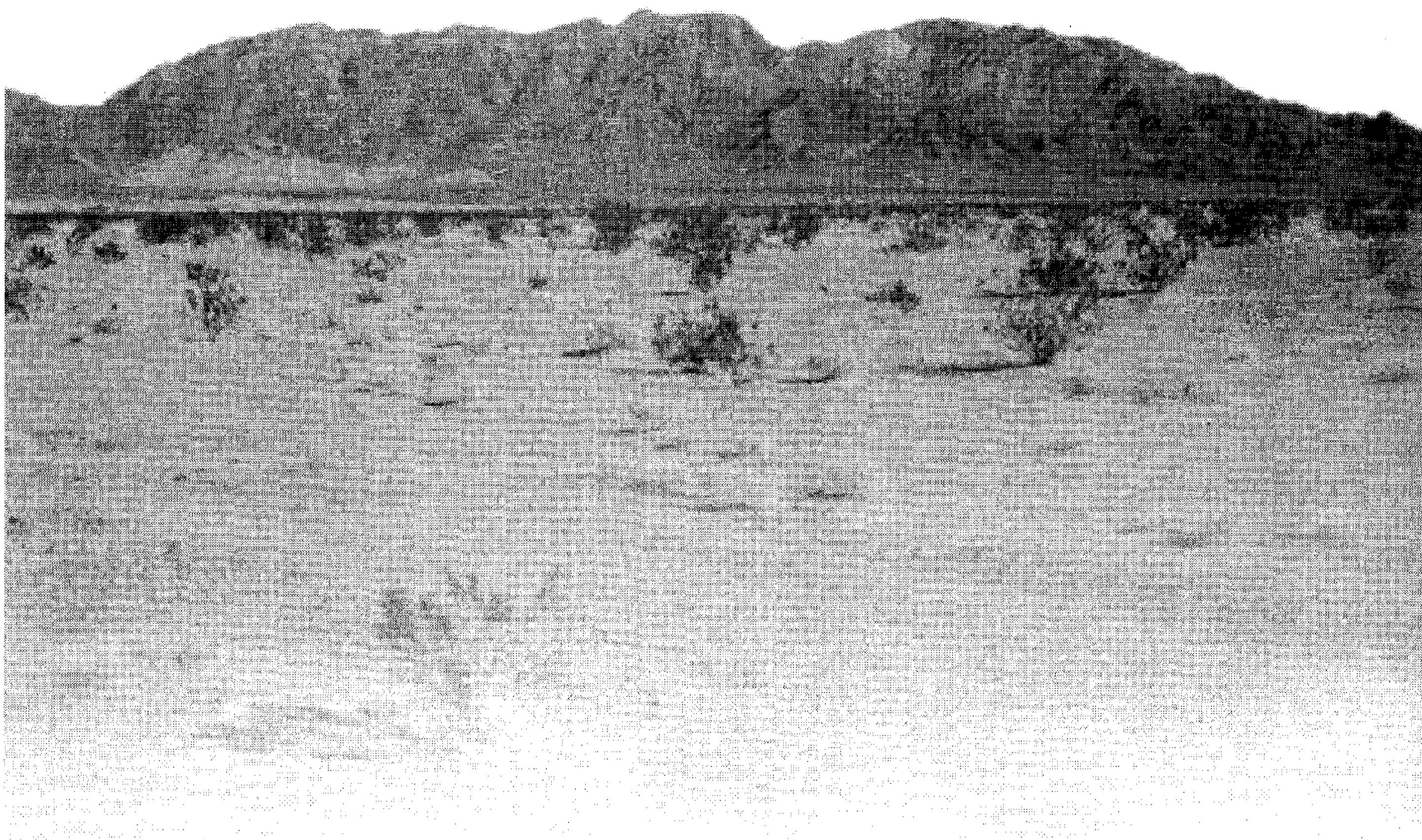
Source: P&D Consultants, Inc. (1999).

Figure 1-1

Alternatives

SECTION 2.0

Water Resources Affected Environment



SECTION 2.0

SECTION 2.0
WATER RESOURCES AFFECTED ENVIRONMENT

This section of the Supplement provides background important to understanding the Management Plan. It describes the regional hydrologic setting of the Cadiz Project area and the geological and hydrological characteristics of the area as they relate to the proposed project.

This section restates and provides clarification of information presented in Section 5.5 of the Draft EIR/EIS. In general, clarification of information contained in the Draft EIR/EIS can primarily be found in Sections 2.4.4 Relationship of Precipitation to Elevation, 2.4.7 Wind Speed, 2.6.4 Faults as Possible Barriers to Groundwater Flow, 2.6.5 Age of Groundwater, and 2.6.6 Groundwater Recharge to the Project Area.

2.1 BACKGROUND

The project spreading basins and wellfield would be located entirely on Cadiz Inc. land, which includes more than 27,000 acres in the Cadiz and Fenner Valleys as shown in Figure 2-1.

Approximately 1,600 acres of this land have been developed for vineyards, citrus orchards, and various types of row crops. Seven groundwater production wells were installed between 1984 and 1994 to provide irrigation for the agricultural operation using water-conserving drip and micro-spray techniques. Current groundwater use for irrigation averages between approximately 5,000 and 6,000 acre-feet/year. A more comprehensive description of the agricultural operation is provided in Section 5.1 of the Draft EIR/EIS.

In 1993, San Bernardino County certified a Final Environmental Impact Report (FEIR) and granted various land use approvals for expansion of agricultural operations on the property up to 9,600 acres (URS Consultants, Inc. 1993 b). As a component of this approval, the County identified specific groundwater monitoring activities to be undertaken by Cadiz. To comply with these monitoring requirements, the Cadiz Valley Agricultural Development Ground Water Monitoring Plan (GWMP) was developed in cooperation with San Bernardino County to monitor all potential environmental impacts that could result from the agricultural operations. As a result of a Memorandum of Understanding (MOU) still in draft form between San Bernardino County, Metropolitan and Cadiz, future groundwater use for all agricultural irrigation in the project area would be subject to the provisions of the Management Plan. This Management Plan incorporates the key provisions of the GWMP.

2.2 PHYSIOGRAPHY AND TOPOGRAPHY

The regional watersheds tributary to the Cadiz Project area are defined by a series of mountain ranges and topographic divides that surround Fenner Valley, Orange Blossom Wash, and the Bristol and Cadiz dry lake depressions as shown on Figure 2-2.

The Fenner Valley watershed, which contributes the principal source of groundwater recharge to the project area, includes all of Fenner Valley and a portion of Lanfair Valley. The boundaries of this watershed are defined by the Marble and

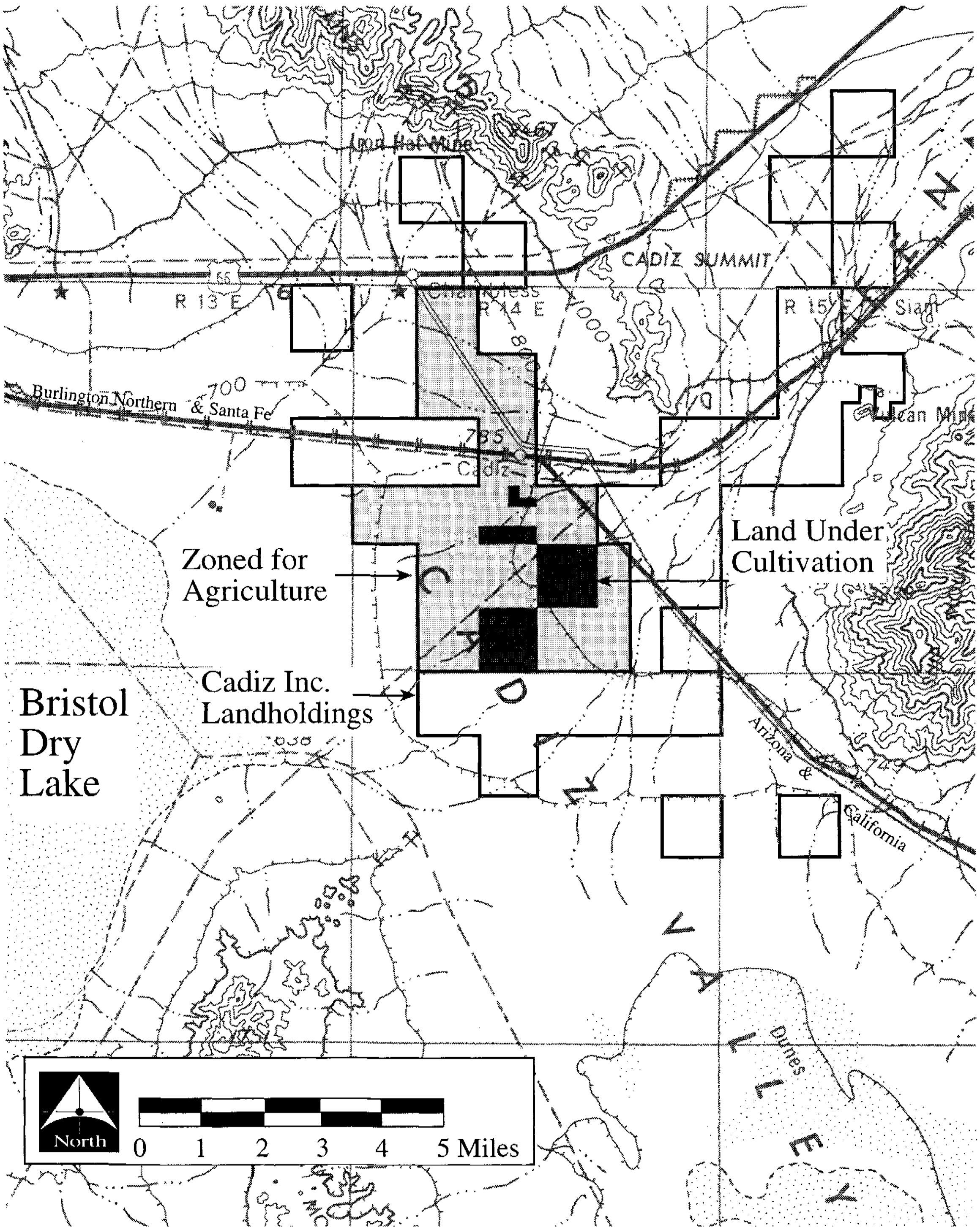
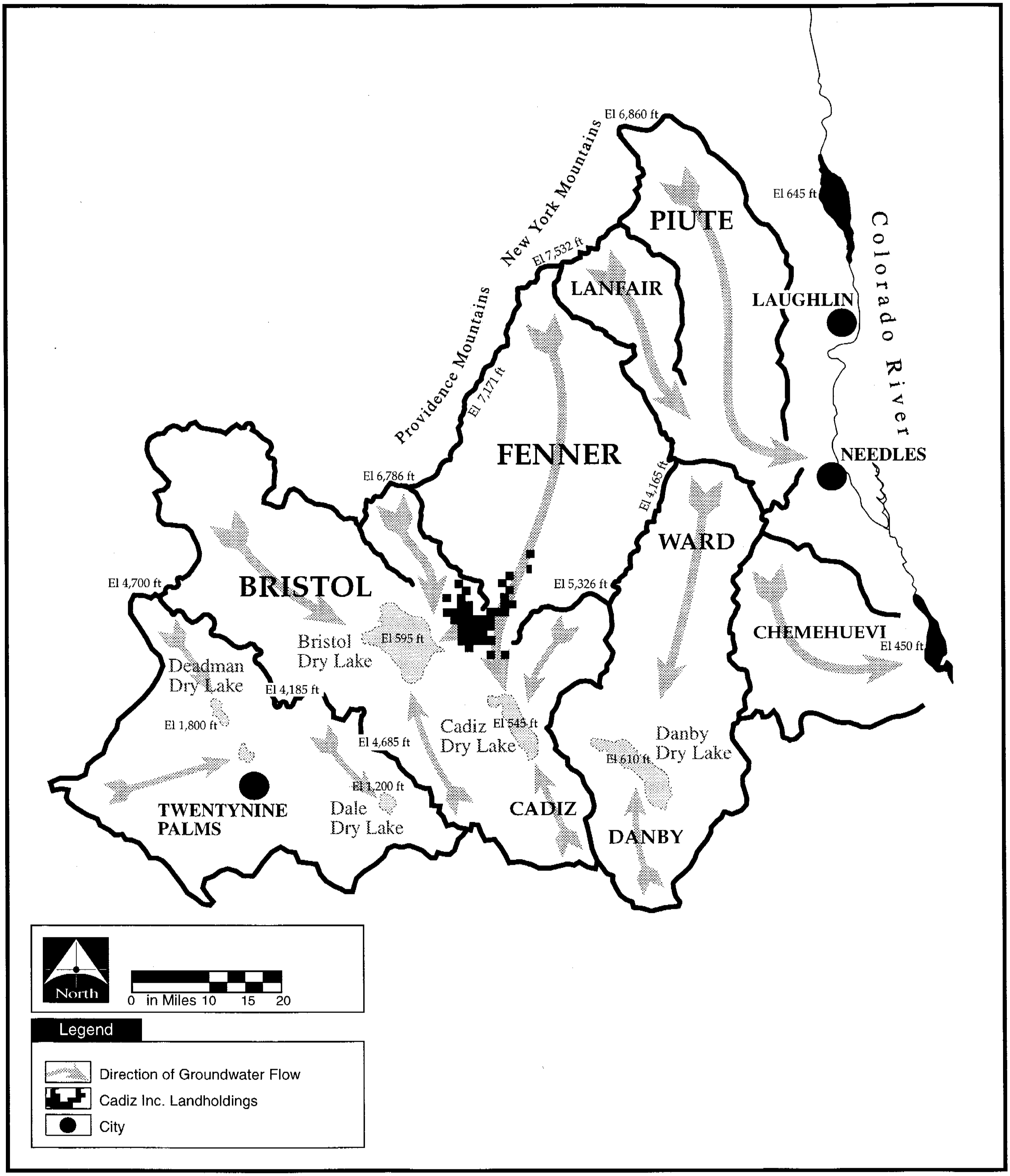


Figure 2-1

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Cadiz Inc. Landholdings and Agricultural Development in the Project Area



Source: Geoscience Support Services, Inc. (1999b).

Figure 2-2

Major Watersheds of the Eastern Mojave Desert

Providence mountains to the west, the New York and Providence mountains to the north, the Piute Range to the northeast, and the Old Woman and Ship mountains to the east. The Clipper Mountains, which reach elevations above 4,600 feet, occur entirely within the Fenner Valley watershed. Elevations within the watershed range from a high of more than 7,500 feet in the New York Mountains to a low of approximately 900 feet in Fenner Gap. Fenner Gap, which forms the surface and groundwater drainage outlet of the Fenner Valley watershed, is located between the Marble and Ship mountains.

The Bristol and Cadiz dry lake depressions are bounded to the southwest by the Bullion, Sheephole, Calumet, and Coxcomb mountains, and to the northeast by the Bristol, Marble, Ship, Old Woman, and Iron mountains. The Bristol and Cadiz depressions are separated by a low surface drainage divide, located on the alluvial fan that formed downstream from Fenner Gap. Bristol and Cadiz dry lakes are located at the low points (elevations of 595 feet and 545 feet, respectively) on either side of this divide.

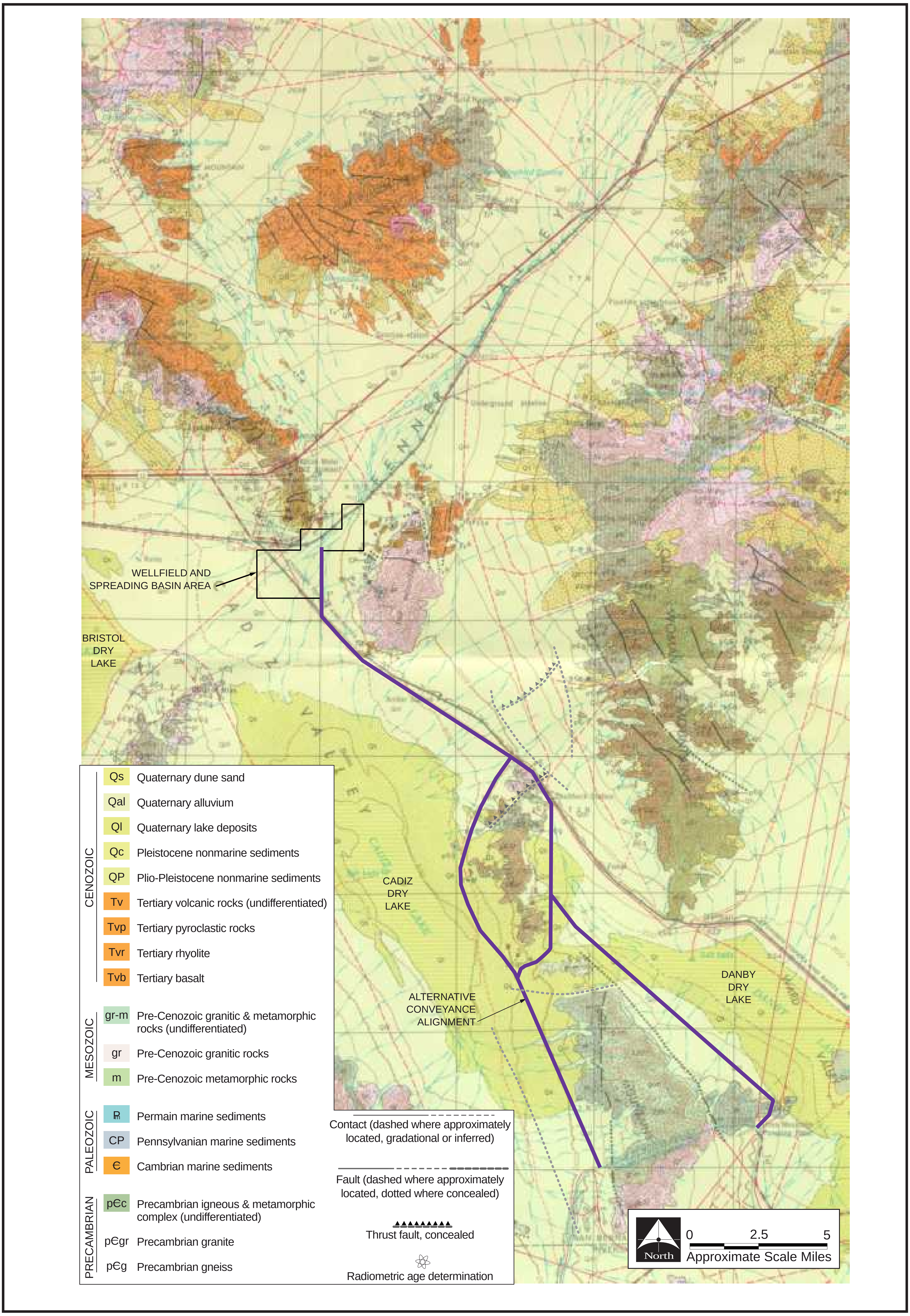
2.3 GEOLOGY

2.3.1 GEOLOGIC SETTING

A detailed description of the geology of the project area is presented in Section 5.4 of the Draft EIR/EIS. The following discussion is intended to provide a general overview of regional stratigraphy and structure pertinent to the surface and groundwater hydrology of the project area. Figure 2-3 shows the locations of proposed project facilities on a regional geologic base map prepared by the California Division of Mines and Geology (Bishop 1963), supplemented with additional data compiled by Howard and others (1989).

The crystalline basement rocks exposed in the mountain ranges of the project area consist primarily of Precambrian granitic and metamorphic rocks, which are locally overlain by a sequence of Paleozoic sedimentary rocks. The Paleozoic rocks consist of sandstones, shales, slates, limestones and dolomites which are depositional equivalents of sediments exposed on the Colorado Plateau, 100 miles to the east. These Paleozoic sediments and the underlying basement rocks have been faulted and folded by numerous periods of regional tectonism. The crystalline basement rocks are generally impermeable and, even where deeply weathered, typically yield only minor quantities of water to wells (Freiwald 1984). Some of the Paleozoic sedimentary section, particularly limestones and dolomites that are fractured or contain solution cavities, may yield large quantities of water to wells although these formations have not been explored extensively (Metropolitan 1999b).

In the Fenner Valley, the Paleozoic section is unconformably overlain by clastic sediments and interbedded volcanic rocks of mid- to late-Tertiary age. The Tertiary volcanic rocks consist of lava flows of basaltic to andesitic composition, and pyroclastic tuffs of rhyolitic to diacritic composition. Dikes of similar composition are exposed in the Marble and Ship mountains. The Tertiary sediments consist of conglomerate, fanglomerate, sandstone, siltstone, water-laid tuff, and lake sediments, which form a composite section more than 7,000 feet thick (Dibblee 1980). The Tertiary sediments and interlayered volcanic rocks are gently dipping, due to extensional normal faulting of late-Tertiary age.



Source: Bishop (1963) and Howard & Others (1989).

Figure 2-3

Geologic Map of the Project Area, Showing Alternative Water Conveyance Alignments

The Quaternary and late-Tertiary alluvial fill in the basins is largely derived from the Precambrian basement rocks, Paleozoic sediments, and Tertiary volcanic rocks. Geophysical evidence indicates that this alluvial fill locally exceeds 3,500 feet in thickness beneath a portion of the project area (Maas 1994). These alluvial sediments form the principal aquifers in the project area.

The playa sediments underlying Bristol, Cadiz, and Danby dry lakes consist of brine-saturated clay, silt, fined-grained sand, and evaporite deposits. The clastic sediments were deposited when stream flow and sheet flow from the surrounding alluvial fans spread onto the playas during major storm events (Gale 1951). The evaporite deposits formed from evaporation of both surface water and groundwater, which seeps into the playa sediments from the adjacent alluvial fans (Rosen 1989).

2.3.2 PROJECT AREA FAULTS AND SEISMICITY

The project area is located at the eastern margin of the "eastern California shear zone" a broad seismically active region dominated by northwest trending right-lateral strike-slip faults (Dokka & Travis 1990). Roughly a dozen fault zones showing evidence of Quaternary movement (during the last 1.6 million years) have been identified in and adjacent to Bristol, Cadiz and Fenner Valleys (Howard & Miller 1992). Cadiz Valley is underlain by two major northwest trending faults, inferred on the basis of gravity and magnetic data (Simpson & others 1984). These fault zones have strike lengths of at least 25 miles, and may merge to the north and northwest with extensions of the Bristol-Granite Mountains and South Bristol Mountains fault zones (Howard & Miller 1992). Right-lateral slip along the Cadiz Valley fault zone of as much as 16 miles has been postulated based on correlation of a distinctive Precambrian gneiss unit across the zone (Howard & Miller 1992).

Bristol Dry Lake is bordered by probable extensions of the Cadiz Valley and South Bristol Mountains fault zones to the east, and by probable extensions of the Broadwell Lake and Dry Lake fault zones to the west (Howard & Miller 1992). Geophysical data indicate this structural depression may exceed 6,000 feet in depth (Simpson & others 1984; Maas 1994). Drill cores recovered from depths greater than 1,000 feet beneath Bristol Dry Lake suggest that subsidence of this basin began by Pliocene time and continues to the present (Rosen 1989), and therefore may be tectonically active.

Fenner Gap appears to be a structural half-graben, formed by a system of northeast trending, northwest dipping normal faults, some of which are found in surface outcrops of the bedrock that flank the gap. The presence of these northeast trending faults beneath the alluvial deposits that underlay the gap can be inferred from gravity and magnetic surveys and a seismic reflection survey conducted across the gap by NORCAL Geophysical Consultants, Inc. (1997).

The seismicity of the project area is described in detail in Section 5.4 of the Draft EIR/EIS. No "active" faults, as defined by the California Public Resources Code (Hart 1994 and Jennings 1994), are known to exist in proximity to the project area.

2.4 CLIMATE

The eastern Mojave Desert is characterized by a desert climate with low annual precipitation, low humidity and relatively high temperatures. Winters are mild and summers are hot, with a relatively large range in daily temperatures. Temperature and precipitation vary greatly with altitude, with lower temperatures and higher quantities of precipitation in the higher elevations.

2.4.1 WEATHER PATTERNS

The seasonal weather patterns of the eastern Mojave Desert region are primarily controlled by semi-permanent high and low pressure systems located over North America and the Pacific Ocean (Houghton & others 1975). During the summer months, a semi-permanent high-pressure cell (the Pacific High), centered over the north Pacific about 1,600 miles west of the California coast, typically diverts low-pressure, moisture-carrying weather systems north of California. The Pacific High contracts and moves southward during the winter months, allowing storms to cross California. Another semi-permanent high-pressure cell (the Great Basin High) is centered over southern Idaho during the winter months and deflects cold Canadian low-pressure weather cells to the east of the project area (Houghton & others 1975). During the summer months, a seasonal low-pressure weather cell (the California Low) often develops over the vicinity of the project area as a result of intense surface heating (Houghton & others 1975).

Two weather stations have provided long-term data in the vicinity of the project area. The Amboy weather station is located on the northern margin of Bristol Dry Lake at an elevation of 625 feet. The Mitchell Caverns weather station is located on the flank of the Providence Mountains, northwest of Clipper Valley, at an elevation of 4,330 feet. Additional short-term data is available from a weather station located in the Fenner Gap portion of the project area. The Management Plan includes provisions for installation of an additional weather station within the higher elevations of the Fenner Valley watershed to provide additional precipitation data for refinement of rainfall and runoff models. Additionally, two meteorological towers would be installed in the region to collect data on wind direction, speed, and frequency as discussed in Section 3.0.

2.4.2 TEMPERATURE

Air temperature in the eastern Mojave Desert region follows a general pattern of high summer and low winter readings. Daily patterns are also typical, with temperatures dropping to an early morning low and climbing to a mid-afternoon high before falling again to the next morning's low temperature (US Ecology 1989). During the winter, the Great Basin High generally protects the region from cold Canadian airflows, typically keeping temperatures above freezing at the lower elevations.

The average winter temperature for the project area is between 50 and 55 degrees Fahrenheit (F), with the average daily maximum near 65 degrees F and the average daily minimum near 40 degrees F (US Ecology 1989). The highest temperatures occur during the summer months, when the average daily temperature is more than 85 degrees F. Average daily maximum temperatures in the summer months are typically around 100 degrees F, although temperatures in excess of 120 degrees F are not unusual. Average daily minimum temperatures during the summer months are around 70 degrees F (US Ecology 1989). The daily temperature range (daily maximum minus daily minimum) is generally 20 to 30 degrees F. This range is greater during the summer months than during the winter months (Thompson 1929).

The average, maximum, and minimum monthly temperatures for the Amboy and Mitchell Caverns weather stations are shown in Table 2-1.

The Mitchell Caverns weather station, located at an elevation of 4,330 feet, has an average annual temperature of approximately 63 degrees F. The floor of Fenner Valley, which ranges from approximately 1,000 to 3,500 feet, is generally a few degrees warmer than Mitchell Caverns. The average temperature at Amboy is higher than that of Fenner Valley due to its lower elevation (625 feet).

2.4.3 PRECIPITATION

Most of the precipitation (both rainfall and snowfall) in the eastern Mojave Desert occurs during the months of November through March (Thompson 1929, U.S. Ecology 1989). However, the frequency and intensity of rainfall from year to year is unpredictable.

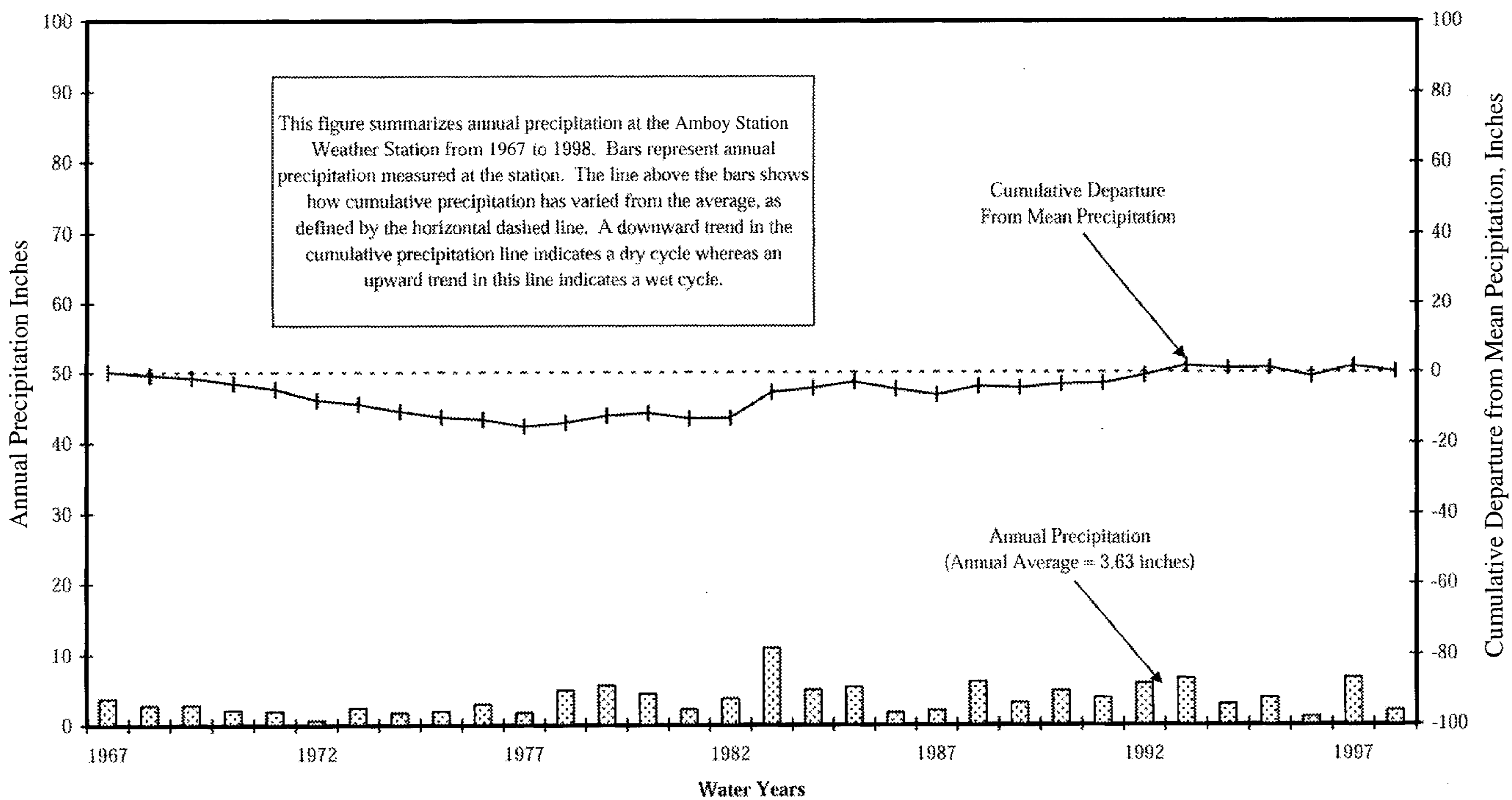
Winter rainfall occurs in events lasting several hours to a day or more. These winter events are typically the result of frontal weather conditions, and rainfall during such events is generally steady. It is not unusual for snow to accumulate at elevations above 5,000 feet in the Fenner and Orange Blossom Wash watersheds. On average, 20 to 30 frontal systems move through the region each winter (Houghton & others 1975; California Air Resources Board (CARB) 1975). However, most of these systems are relatively weak by the time they reach the vicinity of the project area (CARB 1975).

The amount of precipitation in the Bristol, Cadiz, Fenner and Orange Blossom Wash watersheds varies with differences in elevation as shown in Figures 2-4, 2-5 and 2-6. Numerous measurements and estimates have been made. Average annual precipitation from measured data is 3.6 inches on Cadiz and Bristol dry lakes (elevations of 545 to 595 feet), 10.4 inches at the Mitchell Caverns weather station (elevation 4,330), approximately 9 inches at the University of California desert research station in the Granite Mountains (elevation 4,200) (UC Riverside), and is estimated to be approximately 12 inches in the upper elevations of the New York Mountains (NPS Mojave National Preserve Water Resources Scoping Report, 1999). Most of the project area receives only four to six inches of average annual rainfall (Freiwald 1984; Bedinger et al. 1989).

Early summer and late fall are typically periods of little rainfall. Mid- to late-summer rainfall is characterized by localized thunderstorms, induced by the California Low (US Ecology 1989). In general, summer thunderstorms deliver rain in intense bursts of short duration. These

TABLE 2-1
TEMPERATURE DATA

Station	Yearly Average	Maximum Monthly Average	Minimum Monthly Average
Amboy	71.8°F	94.4°F (July)	50.7°F (December)
Mitchell Caverns	62.6°F	82.1°F (July)	46.3°F (January)



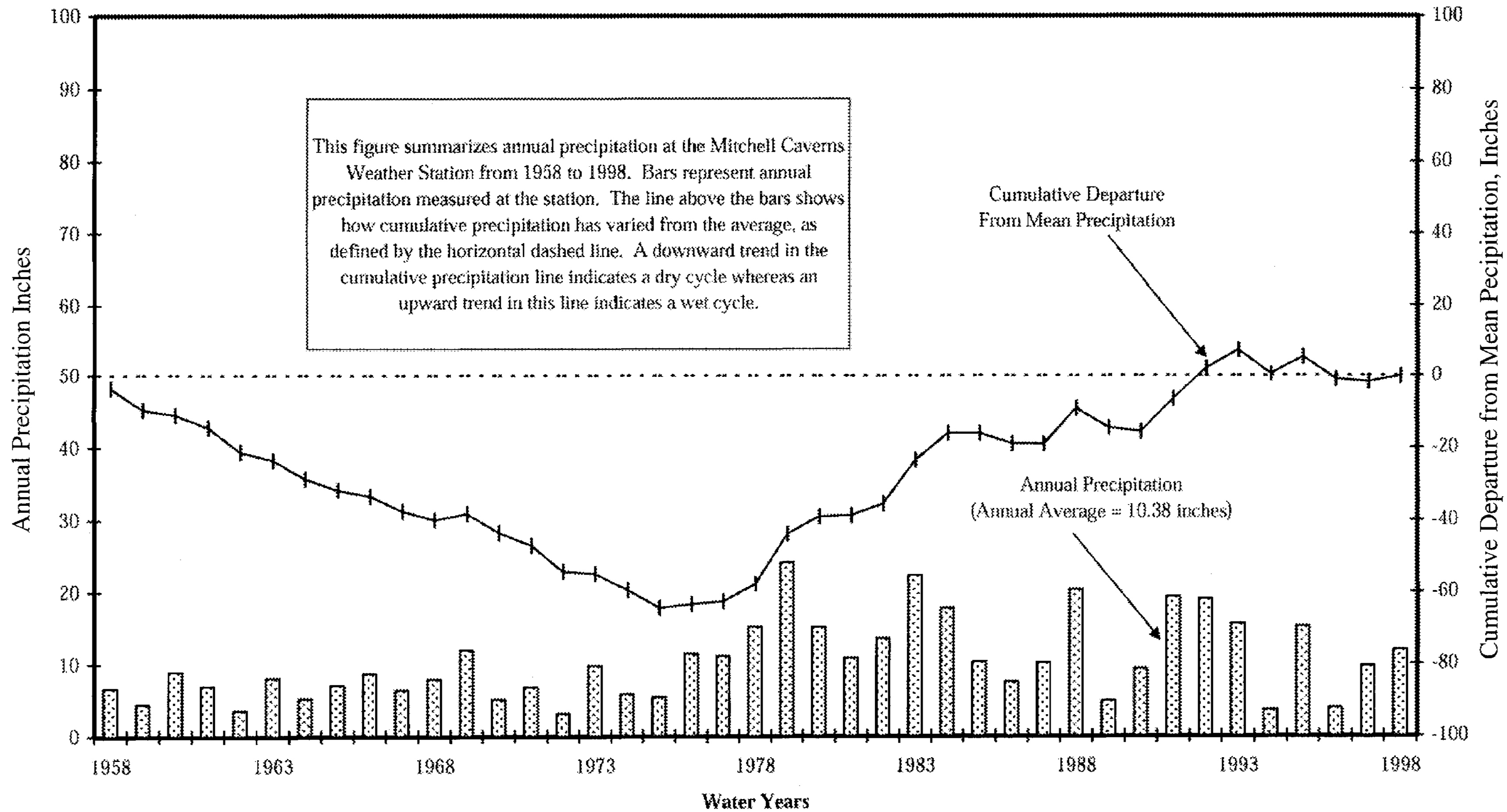
Source: San Bernardino County Flood Control District and EarthInfo Inc.

Figure 2-4

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Annual Precipitation and Cumulative Departure from Mean Precipitation, Amboy Station



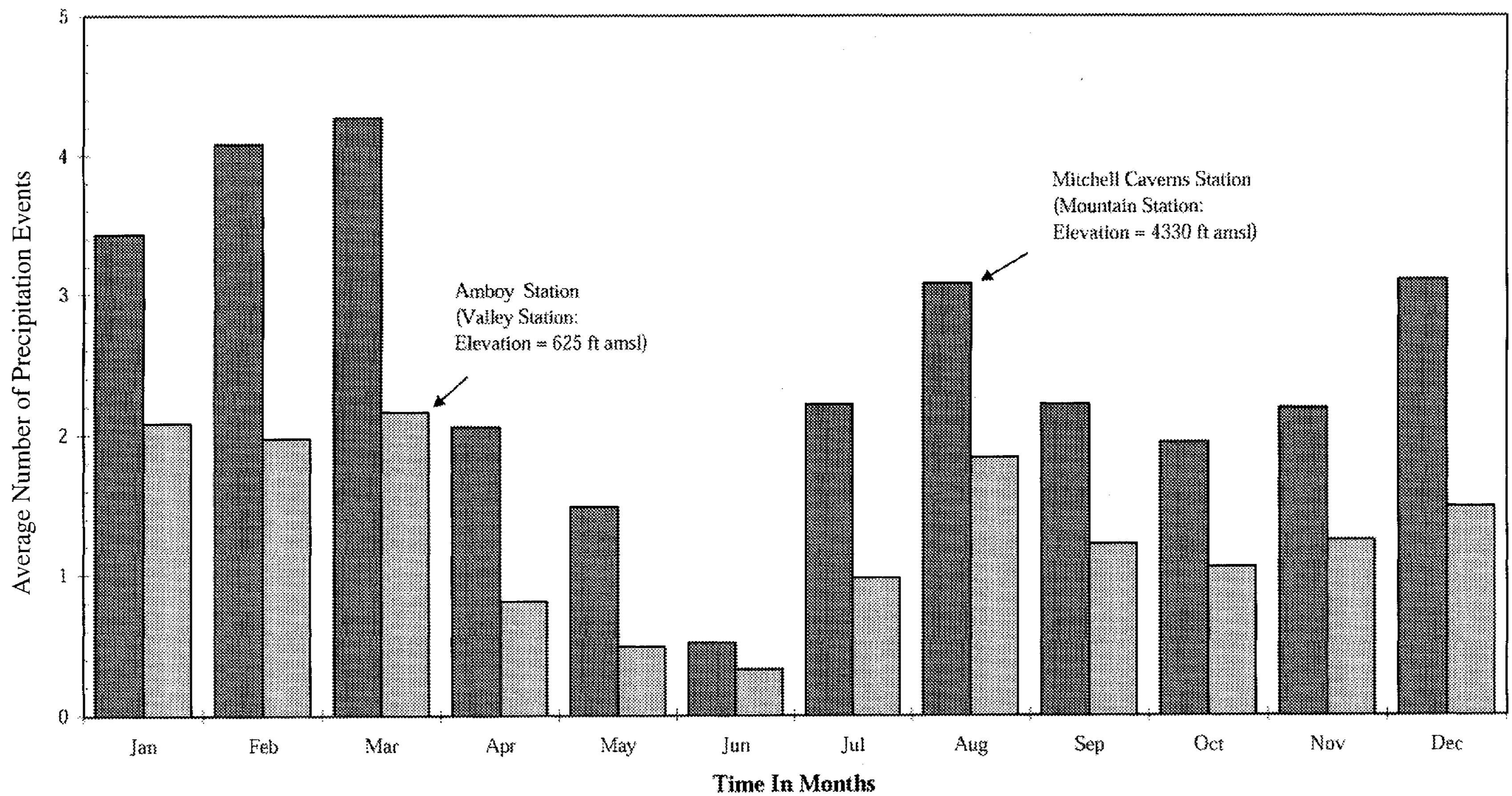
Source: San Bernardino County Flood Control District and EarthInfo Inc.

Figure 2-5

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Annual Precipitation and Cumulative Departure from Mean Precipitation, Mitchell Caverns Station



Source: San Bernardino County Flood Control District

Figure 2-6

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Comparison of Precipitation Frequency Patterns (Mountainous and Valley Regions)

thunderstorms frequently result in flow on the major washes and occasionally result in flash flooding on the valley floors.

2.4.4 RELATIONSHIP OF PRECIPITATION TO ELEVATION

Questions have been raised regarding the relationship of average annual precipitation to elevation within the watersheds tributary to the project area. This relationship is important since estimates of average annual precipitation (both rain and snowfall) are employed in a variety of models used for estimating groundwater recharge. Such models include the "watershed" model employed by Metropolitan (1999b) for estimating groundwater recharge to the project area; the Maxey-Eakin model (1949) developed for use in Nevada; the Crippen model (1965) developed for use in the southern California coastal ranges; and various other "rule-of-thumb" methods that assume recharge to groundwater of specified percentages of average annual precipitation within a watershed.

The Management Plan calls for installation of a new weather station in the higher elevations of the Fenner Valley watershed. Over time, precipitation data from this station would provide important site-specific information regarding the relationship of average annual precipitation to elevation for the regional watersheds tributary to the project area. Further analysis of the regional precipitation data would be considered during the siting of the new weather station called for under the Management Plan.

2.4.5 EVAPORATION RATES

Relatively high temperatures, low humidity, and frequent strong winds result in a relatively high rate of evaporation in the vicinity of the project area (CDWR 1979). Surface water evaporation, as measured using an evaporation pan, is highest in the valleys and lowest in the higher elevations.

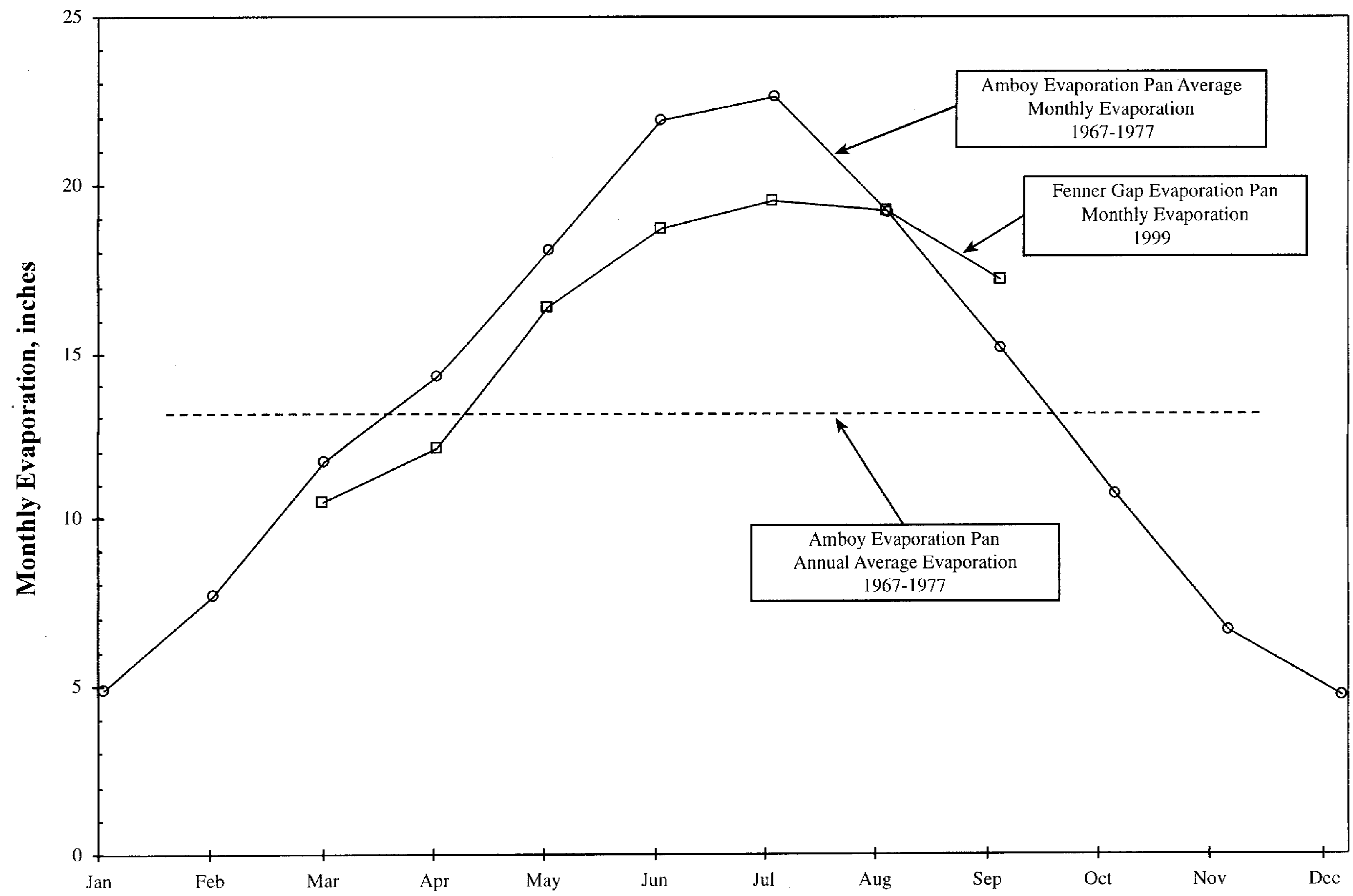
Measured monthly evaporation rates, using an evaporation pan located at the pilot spreading basin in Fenner Gap, are illustrated in Figure 2-7. The measured evaporation rates in Fenner Gap are slightly lower than reported at the Amboy weather station. Amboy evaporation rates range from approximately five inches per month in December and January to more than 22 inches per month in July, with an average annual pan evaporation of 158 inches.

2.4.6 HUMIDITY

The average annual daily relative humidity in the project area is less than 30 percent. Relative humidity is minimal and is often recorded at below 10 percent during the hottest part of the day. Relative humidity occurs at its maximum in the early morning hours, when it ranges from 30 to 50 percent (CARB 1975). The higher early morning relative humidity readings are largely due to the range in daily temperatures (Thompson 1929). No data are available as to the effects, if any, the Cadiz Inc. agricultural operations have had on microclimate humidity.

2.4.7 WIND SPEED

The average annual low-altitude wind speed in the Mojave Desert region is approximately eight miles per hour (mph) (US Ecology 1989), with the highest wind speeds recorded during the summer months (CARB 1975). The prevailing wind direction is from the west. During the spring, the wind is generally from the southwest; during the summer, from the



Source: Metropolitan (1999b).

Figure 2-7

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Comparison of Average Monthly Evaporation for Amboy and Project Weather Stations

south-southwest; during the fall, from the west; and during the winter, from the northwest (CARB 1984). Wind data measured in the project area at Fenner Gap between March and June 1999 indicate steady velocities (not including gusts) of up to 30 mph as shown on Figure 2-8.

Longer-term wind speed data, measured at the northern margin of Bristol Dry Lake, is presented in Figure 2-9 (Jacobs Engineering Group Inc. 1992). This wind rose shows that winds having velocities greater than 21 miles per hour typically blow from the west and northwest. These high-velocity winds may be the most significant determinant in causing mobilization of fine-grained dust and silt from Bristol and Cadiz dry lakes. Two meteorological towers (10-meters tall) would be installed in the region to collect data on wind frequency, direction and speed as discussed in Section 3.0.

2.5 SURFACE WATER

The boundaries of the regional watersheds depicted in Figure 2-2 have been determined from topographic maps, satellite imagery, and field reconnaissance, and are in accordance with previous investigations of the area (Thompson 1929; Freiwald 1984). These regional watersheds form a closed drainage system with no surface outflow (Thompson 1929; Bedinger & others 1989). Instead, all surface water in the vicinity of the project area drains to Bristol and Cadiz dry lakes. The only outlets for surface water are direct evaporation of precipitation, transpiration by vegetation, and evaporation from the lake surfaces (Shafer 1964).

In general, the amount of surface water flow is dictated by the intensity and duration of precipitation, topography, rock type, soil, and vegetation cover. A portion of the precipitation falling in any watershed area is intercepted by vegetation and evaporated. Another portion of the precipitation wets and adheres to the soil before returning to the atmosphere through evaporation. In general, if precipitation exceeds infiltration capacity, overland flow occurs.

There are no measured perennial streams in the Bristol, Cadiz, Fenner, or Orange Blossom Wash watersheds. There are springs and associated intermittent streams distributed throughout these watersheds. Ephemeral runoff within the Bristol depression, including runoff from Orange Blossom Wash, flows into Bristol Dry Lake. Schulyler Wash, the principal drainage in the Fenner Valley watershed, flows through Fenner Gap to Cadiz Dry Lake. See Figure 2-10 for locations of known surface water resources in these watersheds.

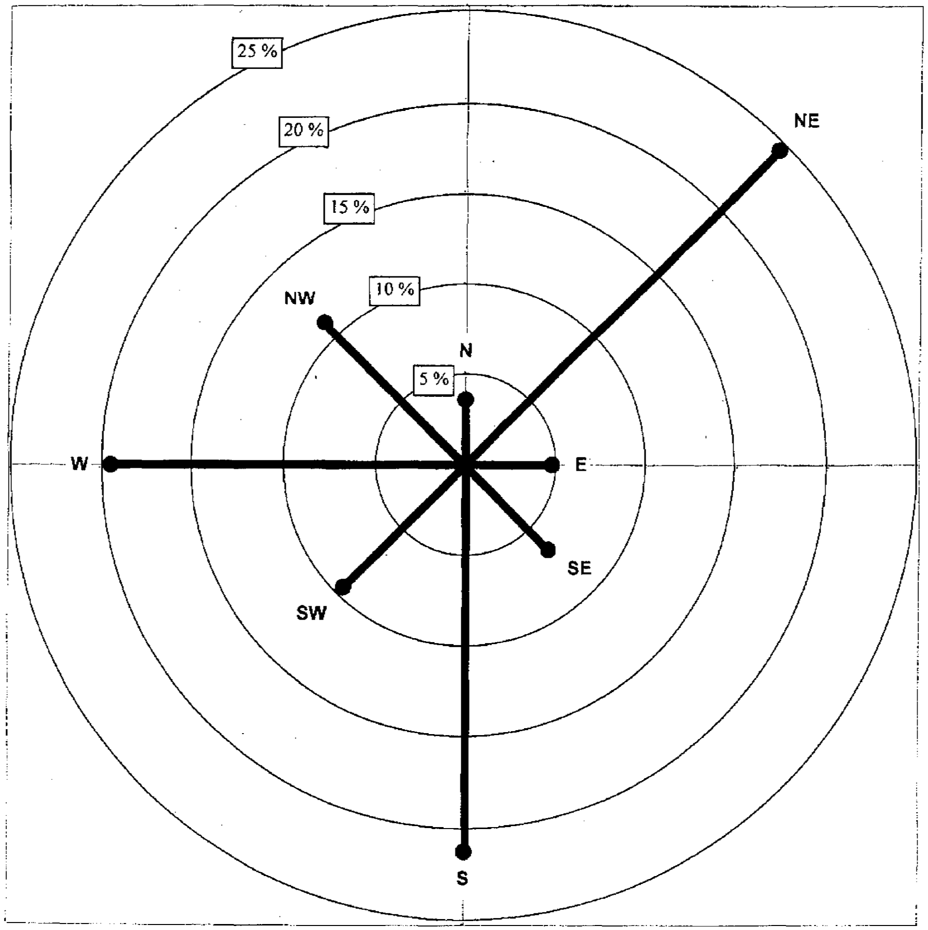
The lake surfaces are normally dry, but runoff from major winter storms and late summer thunderstorms can result in occasional standing water (Bassett & others 1959; Koehler 1983; URS Consultants 1993a, b).

2.6 GROUNDWATER

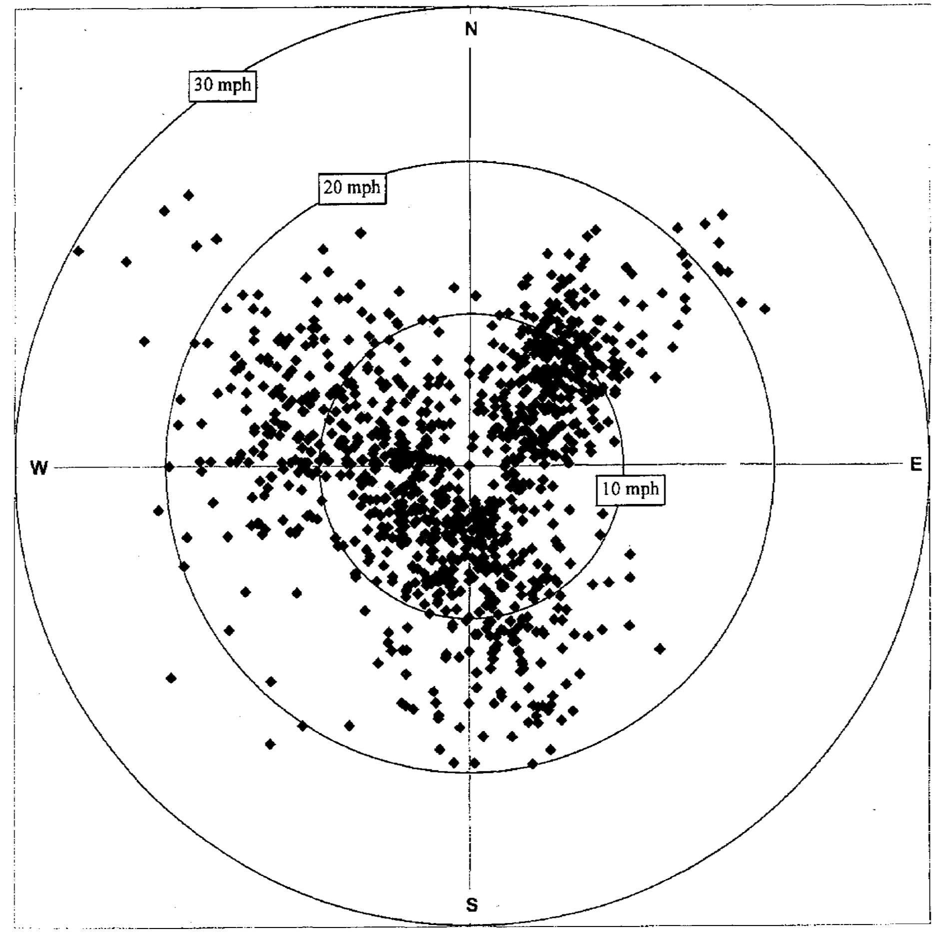
2.6.1 REGIONAL OVERVIEW

The primary sources of replenishment to the groundwater system in the project area include direct infiltration of precipitation (both rainfall and snowfall) in fractured bedrock exposed in mountainous terrain and infiltration of ephemeral stream flow in sandy-bottomed washes, particularly in the higher elevations of the watershed. The source of much of the groundwater recharge within the regional watershed occurs in the higher elevations (Metropolitan 1999b).

WIND FREQUENCY
(Percentage Of Time Wind Blew From Various Directions)
Cadiz Weather Station, Hourly Data, 1-Mar-99 through 15-Apr-99



WIND VELOCITY
(Source Direction And Speed Of Wind)
Cadiz Weather Station, Hourly Data, 1-Mar-99 through 15-Apr-99



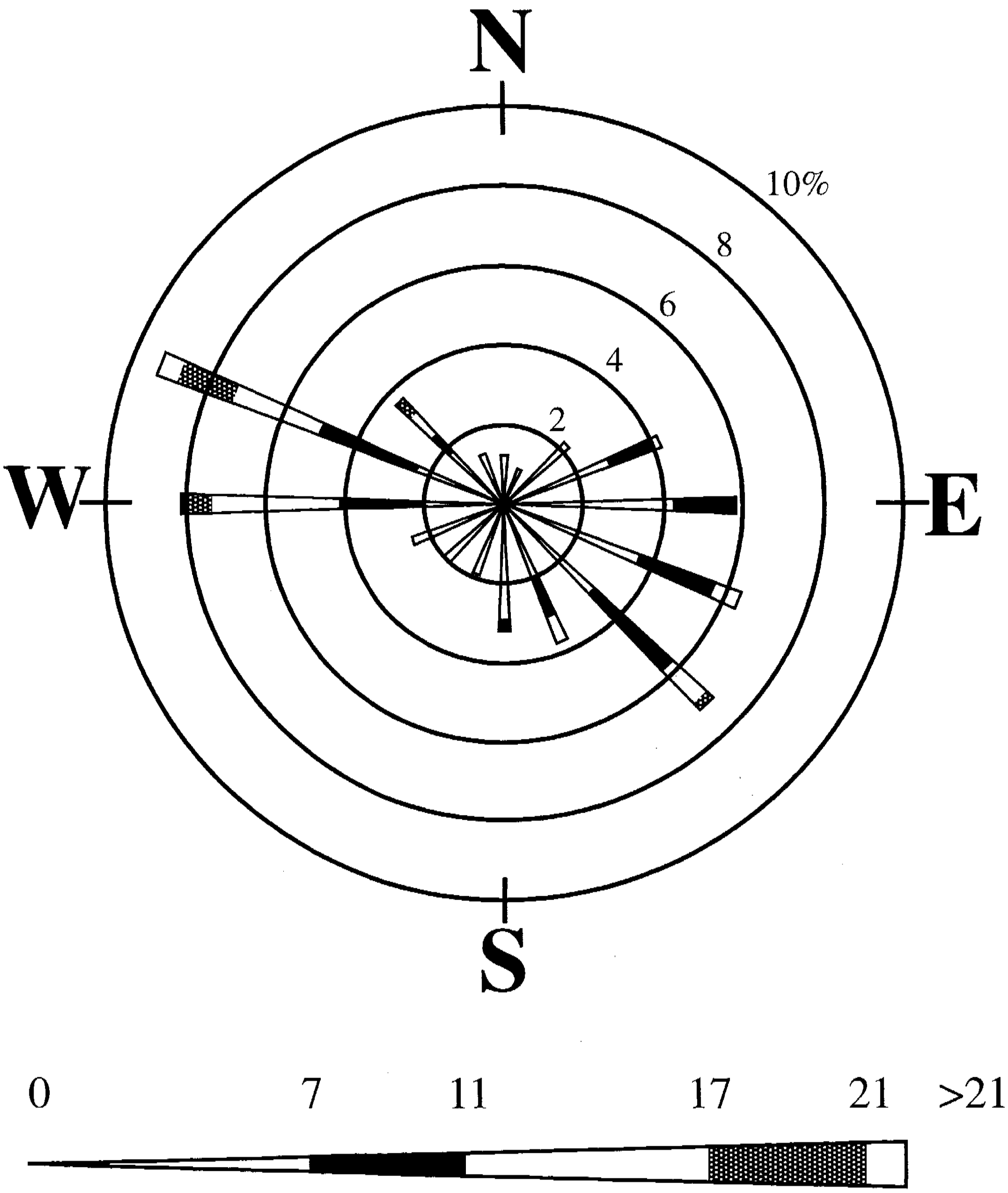
Source: Metropolitan (1999b).

Figure 2-8

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Wind Data Analysis for Project Weather Station



Wind Speed Classes in Nautical Miles/Hour

Frequency of occurrence for wind blowing from each direction.
For example, wind is blowing from the west approximately 8% of the time with a wind speed between 17 and 21 knots for about 0.7% of the time.

NOTE: 1 nautical mile per hour equals 1.15 miles per hour.

Source: Jacobs Engineering Group Inc., 1992

Figure 2-9

Wind Rose for Amboy Weather Station for 1991

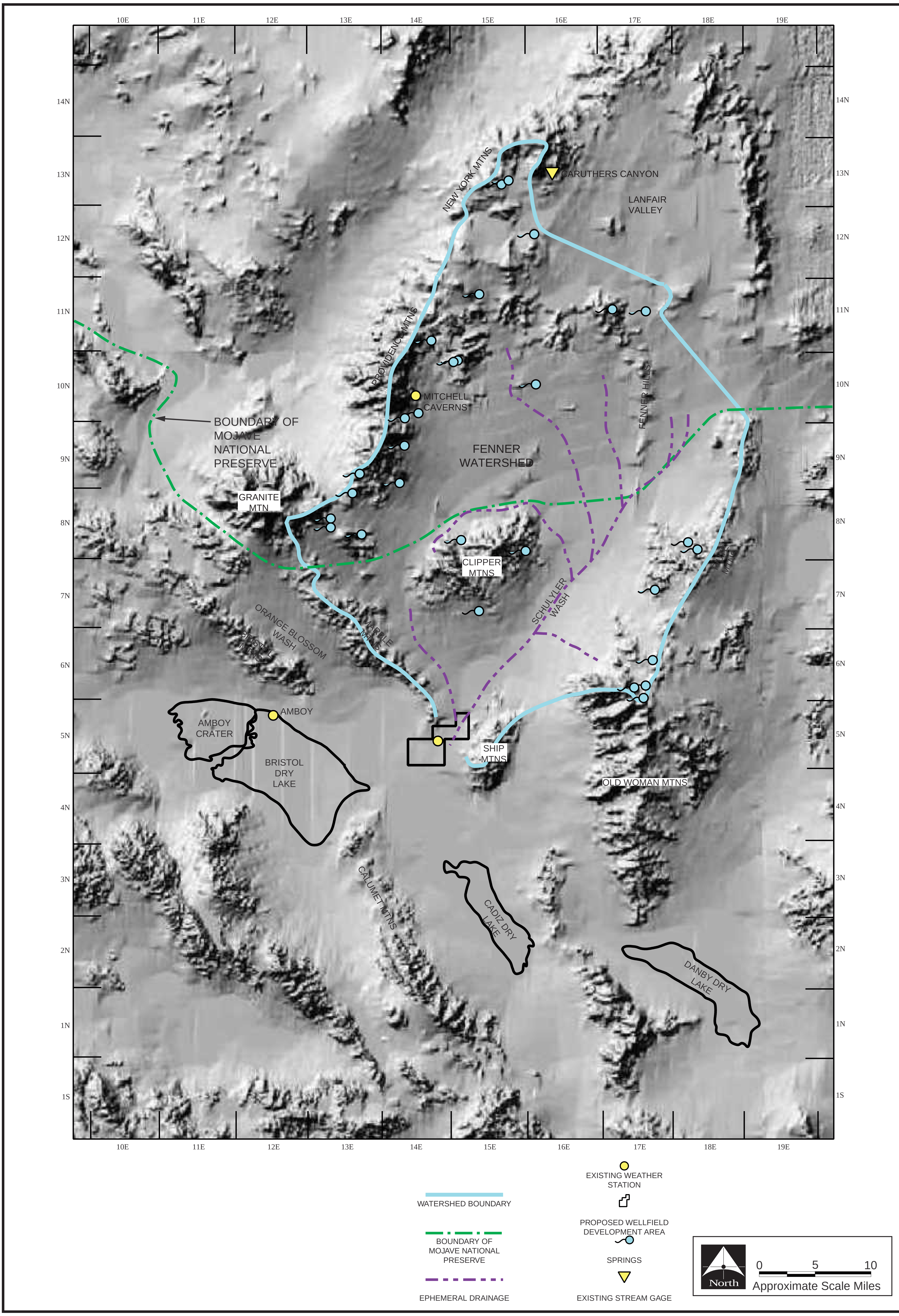


Figure 2-10

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Major Surface Water Drainage Features of the Project Area

Although some groundwater is tapped by vegetation near the range fronts, the remainder moves slowly downgradient through Fenner Valley and Orange Blossom Wash into the Bristol and Cadiz depressions, where it eventually discharges to Bristol and Cadiz dry lakes. Evaporation of groundwater and surface water from the dry lakes over the past several million years has resulted in thick deposits of salt (primarily calcium chloride and sodium chloride) and brine-saturated sediments (Rosen 1989).

Bristol, Cadiz, and Danby dry lakes have static groundwater levels at or near the playa surfaces (Moyle 1967; Rosen 1989). Sodium chloride and/or calcium chloride are currently being recovered from trenches and brine wells on all three of these playas. Thompson (1929), Gale (1951), Bassett and others (1959), Handford (1982) and Rosen (1989) concur that the principal source of groundwater recharge to the playas occurs as diffuse seepage of groundwater into the playa sediments from the adjacent alluvial fans.

The mountain ranges that define the boundaries of the regional watersheds are composed predominantly of granitic and metamorphic basement rock, as described above. This relatively impermeable basement complex forms the margins and bottoms of the aquifer systems (Freiwald 1984). More permeable carbonate bedrock of Paleozoic age occurs locally within the boundaries of these watersheds (as in Fenner Gap).

2.6.2 PRINCIPAL AQUIFER SYSTEMS

The maximum thickness of sediments is unknown, but may be greater than 6,000 feet in the vicinity of Bristol Dry Lake (Maas 1994). Based on available geologic, hydrologic, and geophysical data, the principal formations in the project area that can store and transmit groundwater ("aquifers") have been divided into three general units: an upper alluvial aquifer; a lower alluvial aquifer; and a bedrock aquifer. Figure 2-11 presents a generalized cross-section of this aquifer system from Fenner Valley (to the northeast) across Bristol Dry Lake (to the southwest).

The upper aquifer consists of Quaternary and late-Tertiary alluvial sediments, including stream-deposited sand and gravel with lesser amounts of silt (Moyle 1967; Metropolitan 1999b). The thickness of upper alluvial sediments is approximately 100 to 800 feet (Metropolitan 1999b) as shown in Figure 2-11. The lower alluvial aquifer consists of older sediments, including interbedded sand, gravel, silt, and clay of mid- to late-Tertiary age. Where these materials extend below the water table, they yield water freely to wells but are generally less permeable than the upper aquifer sediments (Moyle 1967; Metropolitan 1999b). Production well PW-1, located in Fenner Gap, draws water primarily from the upper and lower aquifers and yields 3,000 gallons per minute with less than 20 feet of drawdown (Metropolitan 1999b). The Cadiz Inc. agricultural wells draw water from the alluvial aquifers and typically yield 1,000 to more than 2,000 gallons per minute.

Based on findings from recent drilling in Fenner Gap, carbonate bedrock of Paleozoic age, located beneath the alluvial aquifers, contains groundwater and is considered a third aquifer unit (Metropolitan 1999b). Groundwater movement and storage in this carbonate bedrock aquifer primarily occurs in secondary porosity features (i.e. joints,

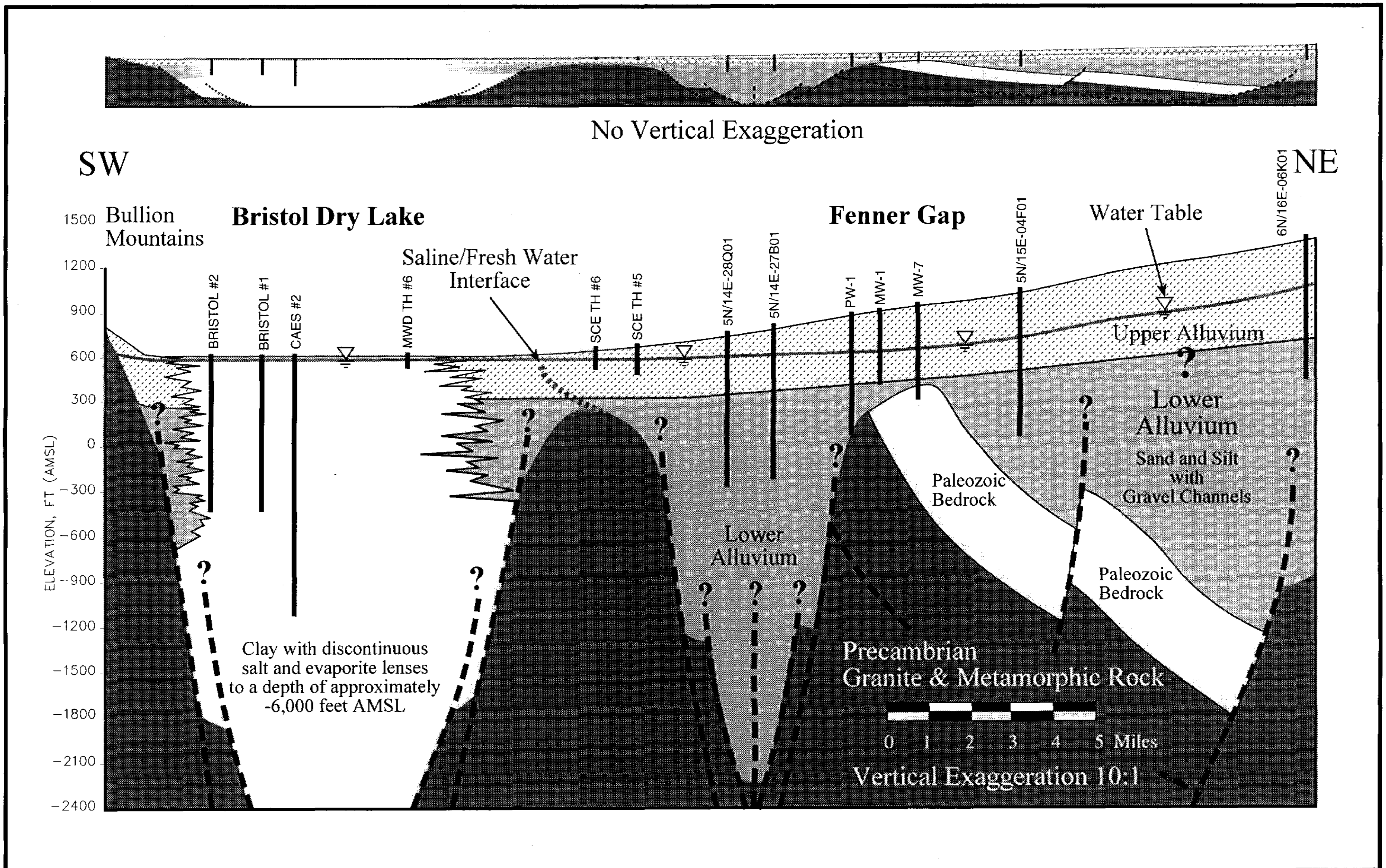


Figure 2-11

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Generalized Aquifer Cross-Section from Fenner Valley to Bristol Dry Lake

faults, and dissolution cavities that have developed over time). The full extent, potential yield, and storage capacity of this carbonate aquifer have not been quantified at this time. Under the guidance of the TRT, the characteristics of the carbonate rock aquifer would be further evaluated as part the Management Plan. However, production wells in the project wellfield would not be drilled into the carbonate bedrock.

As noted above, granite and metamorphic basement rock form the subsurface margins of the aquifer system in the project area. This basement rock is generally impermeable and typically yields only minor quantities of water to wells (Freiwald 1984).

2.6.3 GROUNDWATER FLOW

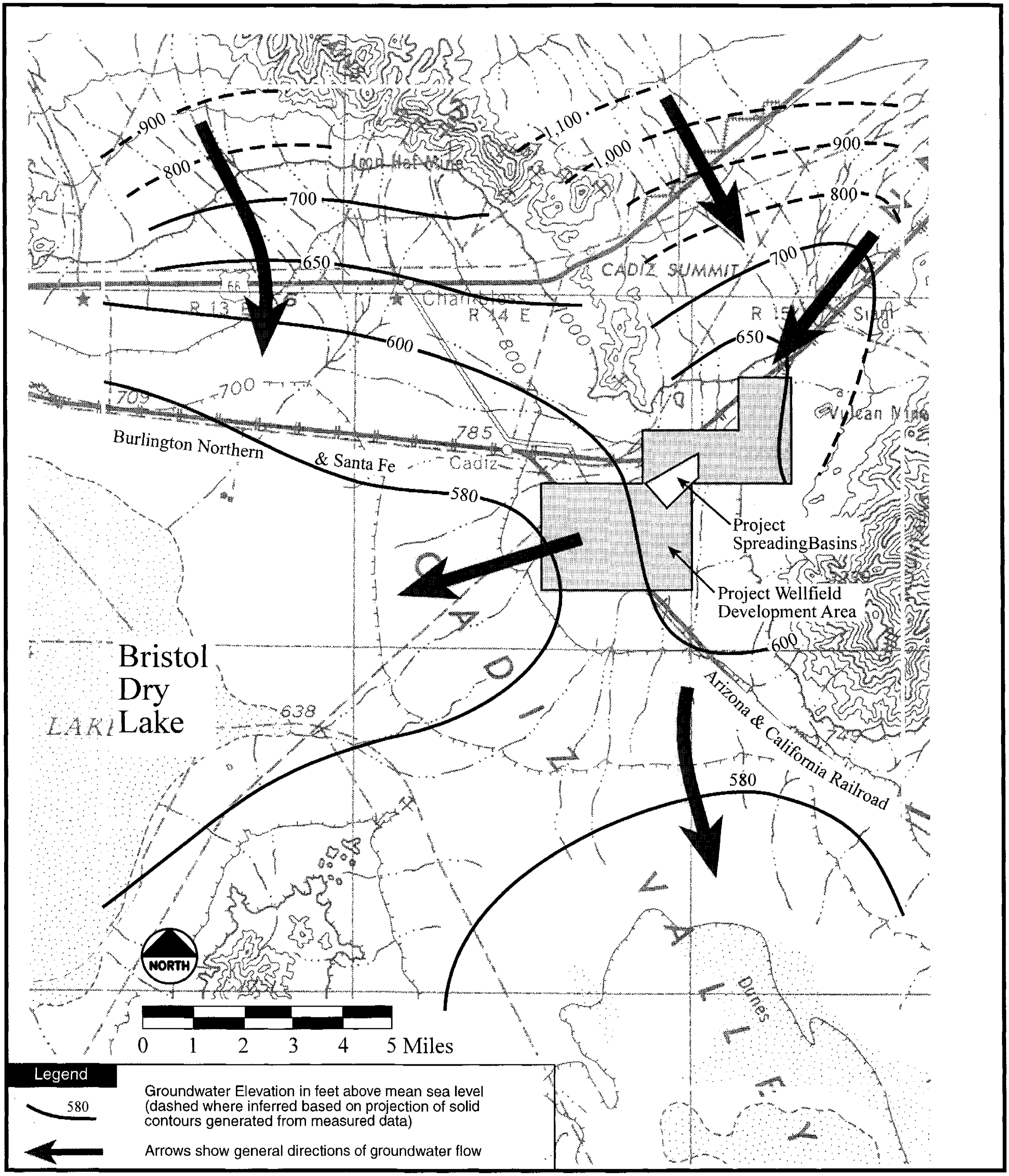
In general, groundwater within the watersheds tributary to the project area flows in the same direction as the slope of the land surface (Metropolitan 1999b). In the Fenner Valley, groundwater generally flows southward and discharges through Fenner Gap toward Bristol and Cadiz dry lakes. In Orange Blossom Wash, located between the Marble and Bristol mountains, groundwater flows generally southward from the Granite Mountains into Bristol Dry Lake.

Figure 2-12 presents a generalized contour map of groundwater elevations and horizontal flow directions in the vicinity of the project area, including the proposed sites for the project spreading basins and wellfield facilities in Fenner Gap. The contours in this figure are based on water levels measured in more than 80 wells. In some cases, published water level elevations have been adjusted to reflect more accurate reference elevations, obtained from updated topographic maps of the area.

The velocity of groundwater flow in the upper aquifer is generally higher than that of the lower aquifer because the upper aquifer sediments are more permeable. Specific groundwater flow rates in the lower alluvial aquifer and the carbonate bedrock aquifer have not yet been quantified in the project area. As outlined in the Management Plan, flow meter surveys would be conducted in applicable observation and production wells to obtain direct measurements of flow velocities within specific aquifer zones. These data would be used to determine which sediments yield water to the production wells as described in the Management Plan.

2.6.4 FAULTS AS POSSIBLE BARRIERS TO GROUNDWATER FLOW

Questions have been raised as to whether subsurface faults may locally act as barriers to groundwater flow in the project area. Although no static groundwater level discontinuities (which could indicate such fault barriers) have been recognized in or adjacent to the project area, such fault barriers, if present, could behave as leaky dams, "ponding" groundwater on the up-gradient side of the faults. It has been suggested that such a stair-step pattern of the water table could lead to misinterpretation of the hydraulic gradient and consequent overestimation of groundwater flow velocities. During the Pre-Operational phase of the project, aquifer testing of both production wells and observation wells combined with measured changes in land surface elevation using Interferometric Synthetic Aperture Radar (InSAR) data would provide additional site-specific information regarding potential fault barriers within the project area. These data would be used to further define the geohydrologic



Source: Metropolitan (1999b).

Figure 2-12

Groundwater Elevation Contour Map for Fenner Gap Portion of the Project Area system used in the Management Plan models.

2.6.5 AGE OF GROUNDWATER

Questions have been raised regarding the age of groundwater based on isotopic analyses of groundwater sampled from wells in the Fenner Gap portion of the project area. As part of the Management Plan, additional isotopic sampling and analysis would be conducted on production wells and observations wells during the Pre-Operational phase of the project to refine estimates of the age of groundwater.

2.6.6 GROUNDWATER RECHARGE TO THE PROJECT AREA

2.6.6.1 Mechanisms of Groundwater Recharge

Groundwater recharge occurs by several different mechanisms within the watersheds tributary to the project area. The principal mechanisms of groundwater recharge are summarized below.

Infiltration into Bedrock

Infiltration of runoff generated by rain fall and snow melt into the bedrock exposed in the mountainous portions of the regional watershed is a significant source of groundwater recharge. A substantial portion of this infiltration may occur directly into the fractured granitic, metamorphic, carbonate, and volcanic bedrock that is exposed in the mountainous areas of the watersheds. Additional study of the characteristics of bedrock infiltration would be conducted under the Management Plan to gain insight into this mechanism of groundwater recharge.

Infiltration into Sandy Washes

Another source of groundwater recharge within the watersheds tributary to the project area is infiltration of runoff into sandy-bottomed washes. Such runoff frequently occurs during major rainstorm events and as a result of melting of winter snowfall in the higher elevations of the watersheds. In addition, major precipitation events of short duration and high intensity frequently result in runoff and sheet flooding, during which surface flow is directed from valley floors onto nearby sandy-bottomed washes.

Questions have been raised regarding the duration of such runoff events, with the suggestion that stream flow occurs only during short periods of time, lasting no more than a few hours to a few days. For example, it has been stated that such short periods of runoff limit the depth to which water can infiltrate, leaving it susceptible to evaporation from the ground surface and transpiration by plants. The quantity of this recharge is unknown.

In order to further evaluate this recharge process, the Management Plan calls for installation of a stream gage (together with both rain and snow gages) at a site in the New York or Providence mountains[1]. Sampling and analysis of soil samples collected during drilling of observation and production wells, as proposed in the Management Plan, would provide further insight into mechanisms of groundwater recharge in valley floor environments. In addition, future watershed modeling would include streamflow routing in order to refine estimates of surface flow duration and rates of infiltration in sandy-bottom washes.

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[1] The installation of the stream flow and precipitation stations would be contingent upon permission from the National Park Service.

Infiltration into Valley Floors

Direct infiltration of precipitation within vegetated portions of the alluvial terrain on the valley floors is not believed to be a significant mechanism of groundwater recharge. Much of the precipitation within such terrain is evaporated directly from the soil surface or transpired by the desert scrub vegetation, which is highly adapted to capture shallow soil moisture. Surface water that infiltrates into such soil is unlikely to penetrate to depths beyond which it is subject to evapotranspiration. The accumulation of water-soluble salts in the upper portions of the alluvium in such terrain is evidence of this process.

2.6.6.2 Estimates of Recharge

A variety of methods have been used to estimate groundwater recharge to the project area. These methods range from simple estimates involving recharge as a percentage of average annual precipitation, to complex relationships between daily precipitation, evapotranspiration, soil moisture, and surface water runoff. Alternative methods for estimating average annual recharge to the project area were suggested by the NPS and San Bernardino County in comment letters submitted in response to the Draft EIR/EIS.

Given the limited availability of site-specific data and current limitations in technology, the current estimates of natural recharge to the project area are considered inconclusive. Due to this uncertainty the Management Plan outlines specific provisions designed to ensure that project operations would not result in any adverse impacts to Critical Resources in the vicinity of the project area, regardless of the amount of natural groundwater recharge.

2.6.7 NATURAL GROUNDWATER DISCHARGE

The primary natural outlet, or discharge, of groundwater from the Bristol, Cadiz, Fenner, and Orange Blossom Wash watersheds is evaporation from Bristol and Cadiz dry lakes. Transpiration by vegetation is not a significant source of groundwater discharge, since no native phreatophyte[2] vegetation occurs in the vicinity of the project area.

Groundwater may discharge locally to springs that have been observed and sampled within several different bedrock units exposed within the watersheds tributary to the project area. Bedrock hosts for these springs include granitic rock in the Granite and Old Woman mountains, shallow intrusive rock in the Providence Mountains, and volcanic sediments in the Clipper Mountains. Many of these springs occur along joints, fractures, and fault zones in the host rock and at the interface of the fractured bedrock and the alluvial fill. Depth of infiltration and residence time for groundwater within fractured bedrock units may be highly variable. Additional study of springs located within the watershed would be conducted, as outlined in the Management Plan, to gain insight into this mechanism of groundwater recharge.

2.6.8 GROUNDWATER USE

The total amount of groundwater pumped in and surrounding the project area has been minimal until the last decade. The primary groundwater uses in the region are the Cadiz Inc. agricultural operations, the Burlington Northern Santa Fe Railroad (BNSF), the various salt-mining companies operating on

[2] Types of vegetation that draw water from the saturated zone.

Bristol and Cadiz dry lakes, and the few residents in and around the communities of Chambless and Essex.

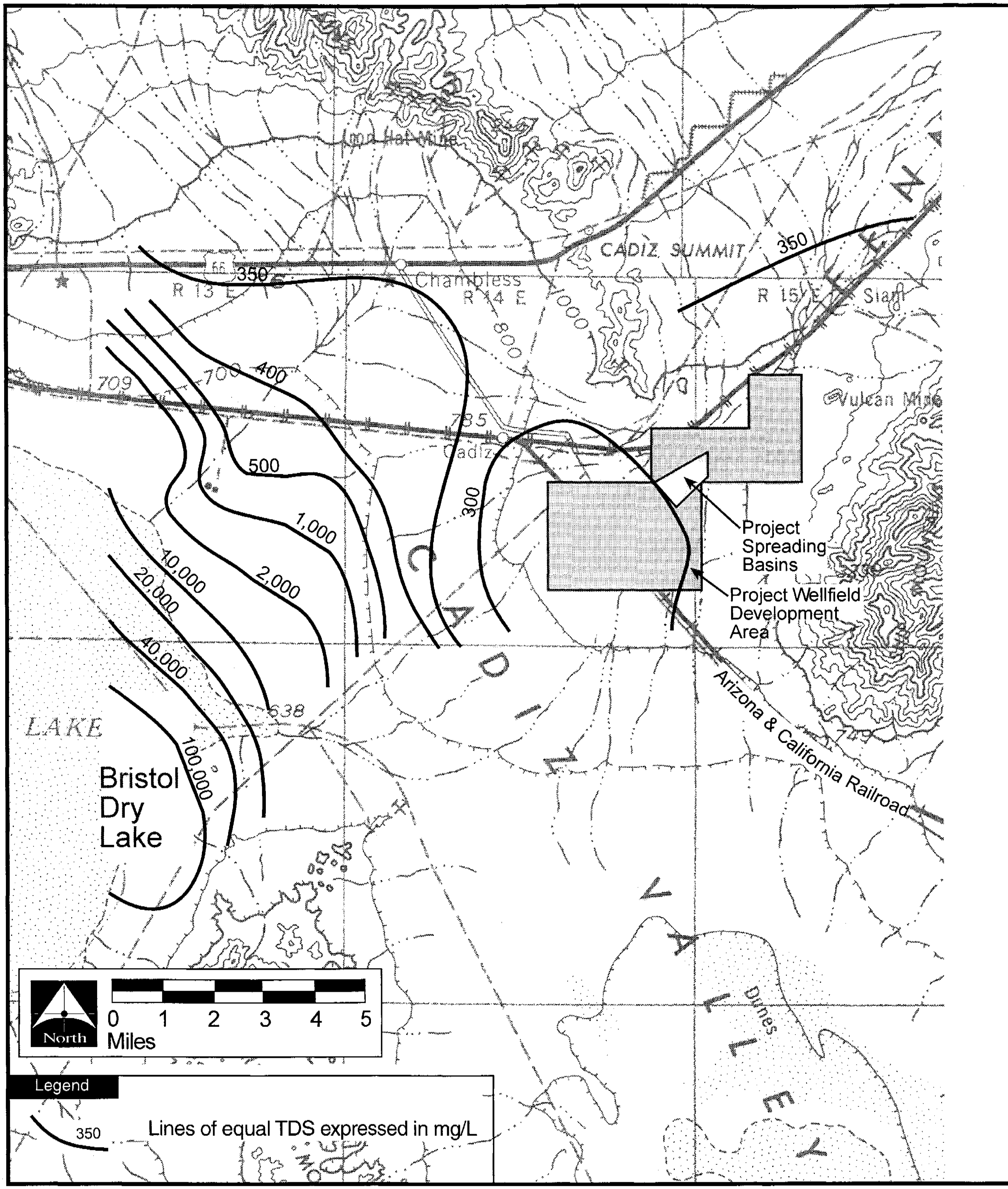
Between 1901 and 1947, approximately 2,365 acre-feet of groundwater, or an average of 50 acre-feet per year, was produced from Fenner Valley (Shafer 1964). Between 1948 and 1962, Shafer (1964) estimates that approximately four acre-feet per year were pumped from Fenner Valley. The sharp drop in production was attributed to a switch from steam- to diesel-powered engines on the railroad. Freiwald (1984) estimates that between 1954 and 1981, groundwater pumping in Fenner Valley remained constant at approximately seven to eight acre-feet/year. Using Freiwald's (1984) pumping rate estimate for 1954 through 1981, and assuming that this rate continued through 1998, the total volume of groundwater estimated to have been pumped from this valley since 1901 ranges from approximately 2,700 to 2,750 acre-feet.

Shafer (1964) reports that approximately 14,300 acre-feet of fresh water were pumped from the Bristol and Cadiz valleys from 1910 (when the first fresh water well was drilled) to 1964, or an average pumping rate of approximately 265 acre-feet per year. Assuming these historical pumping rates continued from 1964 through 1998 (not including the Cadiz Inc. agricultural operations), a total of approximately 9,000 additional acre-feet was pumped from these valleys during this time period. In addition, from 1983 through 1998, the Cadiz Inc. agricultural operations produced approximately 61,740 acre-feet of groundwater from its wellfield. Yearly groundwater production for the Cadiz Inc. agricultural operations has averaged 5,000-6,000 acre-feet per year from 1986 through 1998. Accordingly, the total amount of groundwater pumped from the Bristol and Cadiz valleys from 1910 through 1998 is approximately 85,000 acre-feet.

Calcium chloride and sodium chloride are produced by mining operations on both Bristol and Cadiz dry lakes. The highly saline brine is pumped from brine wells and from trenches for concentration in evaporation ponds. These mining operations are conducted on patented lands and on unpatented claims on Federal land administered by the BLM. The amount of brine produced is proprietary information, and precise estimates are unavailable. The Management Plan provides for a comprehensive program of monitoring designed to ensure that project operations would not adversely impact these brine resources.

2.6.9 GROUNDWATER QUALITY

With the exception of the areas underlying and immediately adjacent to Bristol and Cadiz dry lakes, the quality of the groundwater in the Fenner Gap portion of the project area is relatively good, with TDS concentrations averaging approximately 300 milligrams per liter (mg/L), as shown in Figure 2-13. The TDS concentration in Fenner Valley groundwater is typically in the range of 300 to 400 mg/L. On Bristol and Cadiz dry lakes, surface water and shallow groundwater evaporation has concentrated dissolved salts, resulting in TDS concentrations as high as 298,000 mg/L (Schafer, 1964). The location of the interface between the low-TDS "fresh" groundwater and high-TDS "saline" groundwater underlying the dry lakes has been mapped on the basis of data from observation wells in the area (Shafer 1964; Rosen 1989).



Source: Metropolitan (1999b).

Figure 2-13

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Total Dissolved Solids in Groundwater in the Fenner Gap and Bristol Dry Lake Areas

2.7 SPRINGS AND PHREATOPHYTE VEGETATION

No springs or native phreatophyte vegetation are in the project area. The closest springs to the project area are located in the Granite, Clipper and Old Woman mountains, more than 10 miles from the proposed spreading basins and wellfield. Because springs located within the Mojave National Preserve, within designated BLM Wilderness Areas, and within other BLM-managed areas within the affected watersheds are considered Critical Resources (see Section 3.2), the Management Plan outlines a comprehensive program for monitoring and is designed to prevent any adverse impacts to such springs as a result of project operations. Figure 2-14 shows the location of the Mojave National Preserve and nearby communities in relation to the project area and the regional watersheds of the eastern Mojave.

2.8 DUST MOBILIZATION FROM BRISTOL AND CADIZ DRY LAKE BEDS

Questions have also been raised about the potential for the Cadiz Project to indirectly increase the amount of dust mobilized from the surface of Bristol and Cadiz dry lake beds resulting from project operations. It is currently believed that the groundwater (brine water) beneath the lakebeds is sufficiently near the ground surface to moisten the surface soils through the capillary rise of moisture off of the water table. It is believed this process reduces the amount of dust generated on the dry lakes because the surface moisture holds the soil together. Because the brine beneath the lakebeds is believed to be hydraulically connected to the freshwater aquifer outside the dry lakes, excessive lowering of the groundwater surface at the margins of the dry lakes could lower brine levels beneath the lake beds to the point that the capillary rise does not reach the ground surface. If this were to happen, the surface soils could dry out, resulting in an increased potential for dust mobilization during wind storms. A regional study (Reheis and Kihl 1995) of dust deposition in southern Nevada and southeastern California found that climatic factors that affect dust interact with each other as well as source type, source lithology, geographic area and human disturbance. The study also found that the rate of dust accumulation mostly reflects changes in annual precipitation rather than temperature, and that playa and alluvial sources respond differently to annual changes in precipitation.

The US Environmental Protection Agency (USEPA) designated a major portion of the San Bernardino County area of the Southeast Desert Air Basin as a moderate nonattainment area for the PM_{10} National Ambient Air Quality Standards. The designation was based on a number of violations which occurred in the populated areas of the Mojave Desert Air Quality Management District (MDAQMD) during the period 1989-1991. However, although PM_{10} concentrations have not been monitored in the sparsely populated eastern portion of San Bernardino County, the USEPA has included the eastern portion in the PM_{10} nonattainment area. In consideration of the locations of the observed violations and the sources of PM_{10}, the MDAQMD prepared and submitted to USEPA a PM_{10} attainment plan that identifies a smaller nonattainment area surrounding the heavily populated cities and towns in the MDAQMD. This region includes the Victor Valley, Morongo Basin, Barstow, and Lucerne Valley, and is referred

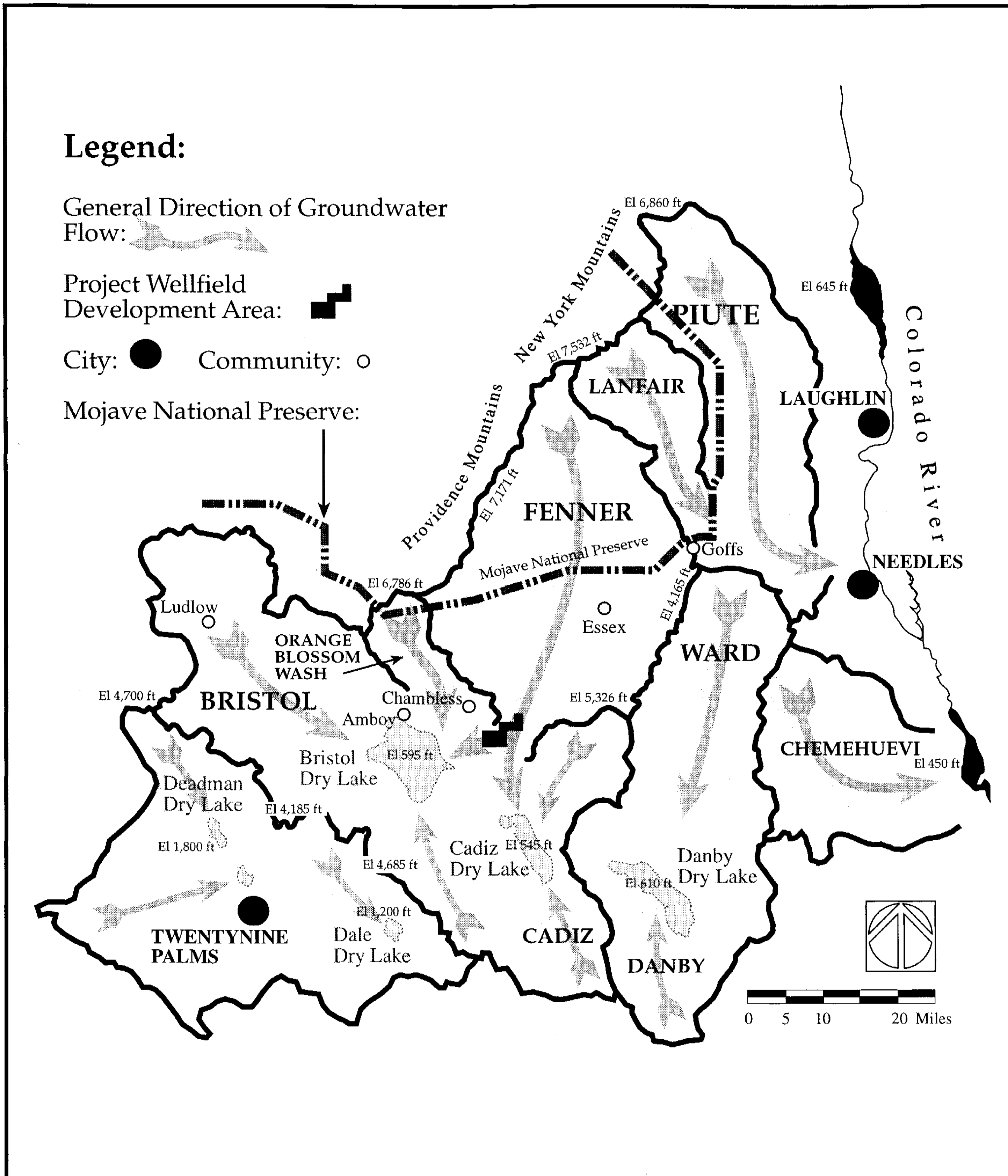


Figure 2-14

Cadiz Groundwater Storage & Dry-Year Supply Program

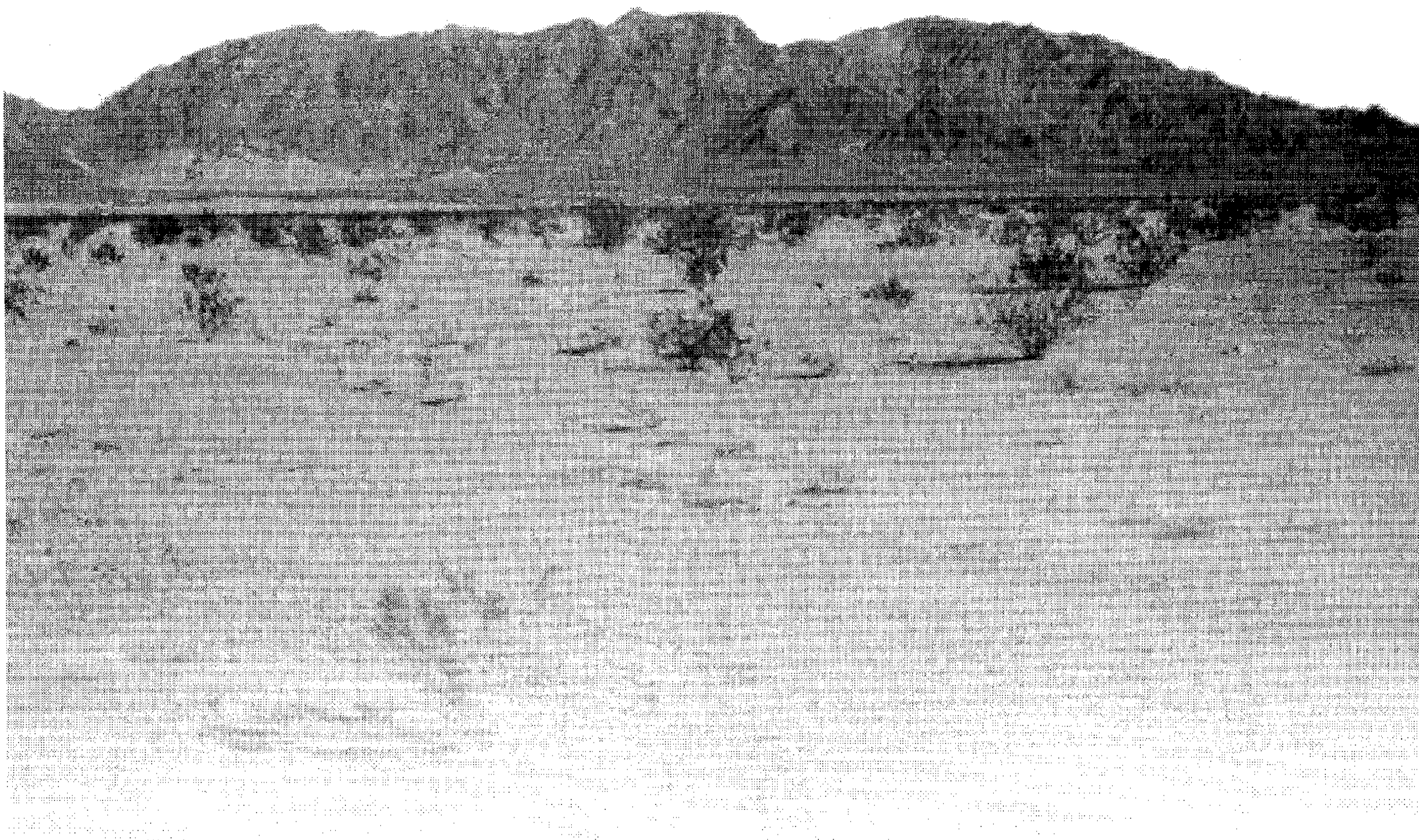
Supplement to the Draft EIR/EIS

Location of Mojave National Preserve and Nearby Communities in Relation to the Regional Watersheds in the Vicinity of the Project Area to as the Mojave Desert Planning Area. The MDAQMD has also requested that the eastern portion of San Bernardino County be redesignated as unclassifiable for PM_{10}. USEPA has not approved that request.

The Management Plan includes specific provisions designed to prevent the mobilization of dust as a result of project operations. Due to the possible relationship of groundwater levels beneath the dry lakes to dust mobilization at the dry lake surfaces, a key monitoring feature would be monitoring well clusters at the margins of Bristol and Cadiz dry lakes which would provide early warning monitoring of groundwater level changes resulting from project operations. The Management Plan also includes provisions for the monitoring of lake bed surface soil moisture and direct measurement of airborne dust. Additionally, to determine whether any project-mobilized lakebed dust could be transported to a Class I area designated by the Clean Air Act (currently applies to Joshua Tree National Park), regional meteorological towers would be installed to better determine the speed and direction of winds in the region.

SECTION 3.0

Groundwater Monitoring and Management Plan



SECTION 3.0
GROUNDWATER MONITORING AND MANAGEMENT PLAN

Included here in its entirety is the Draft Groundwater Monitoring and Management Plan (Management Plan) for the Cadiz Groundwater Storage and Dry-Year Supply Program. Because the Management Plan will also be bound separately as a stand-alone document for future use, it includes introductory text that is repetitive of prior sections of this Supplement.

3.1 INTRODUCTION

This Management Plan is an integral part of the Cadiz Project. It would govern water storage and extraction. The Management Plan is designed to ensure there would be no adverse impacts is by providing "early warning" of potential adverse impacts to Critical Resources that could result from Cadiz Project operations. With such early warning, adverse impacts would be prevented by implementation of corrective actions. Critical Resources identified in the Management Plan are as follows:

- Springs within affected watersheds including springs of the Mojave National Preserve and BLM-Managed Lands.
- Aquifer System.
- Brine Resources of Bristol and Cadiz Dry Lakes.
- Air Quality in Joshua Tree National Park, Mojave National Preserve and BLM-Managed Lands.

The Management Plan would establish a comprehensive network of monitoring and data collection facilities combined with procedures for comprehensive scientific review of all actions and decisions. The Management Plan mandates specific Action Criteria (trigger levels) and specified responses if an action criterion is reached. It establishes a defined process for scientific review of groundwater management, weather and air quality information, and when appropriate, a process to make recommendations to protect Critical Resources. Management Plan reports would be of public record.

The Management Plan has been prepared by the Bureau of Land Management (BLM), National Park Service (NPS), United States Geological Survey (USGS), Metropolitan, the County of San Bernardino, and Cadiz Inc. It would be implemented under the guidance of a Technical Review Team (TRT) and direction from a Basin Management Group (BMG). Both the TRT and the BMG would be comprised of representatives from federal and county government, Metropolitan and Cadiz Inc.

The TRT and the BMG would provide a forum for the Department of the Interior agencies, the County of San Bernardino, Metropolitan, and Cadiz Inc., to discuss the results of monitoring and management activities and to exchange interpretations of the data and information in an effort to achieve consensus on project-related issues.

Prior to the publication of the Final EIR/EIS, the details of the structure and function of the TRT and BMG relative to implementing the Management Plan will be developed. Regardless of how these specifics develop, the BLM would retain ultimate control over compliance with the Management Plan through terms and conditions of any right-of-way grant(s) it issues.

The TRT would review data, provide technical interpretations, and make recommendations to the BMG. The BMG would consider the recommendations of the TRT. In the event that there was not a consensus recommendation by the TRT, the BMG would attempt to resolve issues. If the BMG did not reach consensus, the BLM would retain ultimate control over the enforcement of the terms and conditions of any right-of-way grant(s) it issues. The composition, duties and responsibilities of the TRT, BMG, and BLM and the decision-making process are described in Sections 3.9 and 3.10. Under the guidance of the TRT and BMG, the Management Plan would be implemented with an initial set of monitoring features and parameters developed from existing data as described in Section 3.4.

The term "feature" refers to any fixed object, either natural or man-made, from which data would be collected. Man-made features include wells from which water level measurements and water quality samples could be retrieved, weather stations, staff gages, etc. A detailed list of monitoring features is shown in Table 3-1. As new data become available during project operations, these features and parameters would be refined as necessary to protect Critical Resources in and adjacent to the project area.

The project would be comprised of three phases: a Pre-Operational phase[1], an Operational phase of 50 years, and a Post-Operational monitoring phase of 10 years or as recommended by the TRT and approved by the BMG during project operations in accordance with the Management Plan.

[1] The Pre-Operational phase would last approximately 15 to 24 months and ends with the completion of construction of facilities necessary to store water in the project area.

3.1.1 LOCATION OF PROJECT AREA

The Cadiz Project is located in eastern San Bernardino County as shown in Figure 3-1. The project spreading basins and wellfield would be located on Cadiz Inc. land, centered in the vicinity of Fenner Gap, located between the Marble and Ship mountains as shown in Figure 3-2.

3.1.2 PROJECT OBJECTIVES AND DESCRIPTION

The Cadiz Project has two objectives:

- Provide conjunctive-use storage of up to 150,000 acre-feet of imported Colorado River water per year, and total storage at any given time of up to 1 million acre-feet without adversely impacting Critical Resources. Water to be stored would be conveyed from Metropolitan's Colorado River Aqueduct (CRA) to spreading basins in the project area during periods of surplus supply. This stored water would subsequently be extracted by the project wellfield and conveyed back to the CRA as needed.

    - Transfer (provide for the extraction and delivery) of indigenous groundwater to the CRA in compliance with the provisions of this Management Plan, including the avoidance of adverse impacts to Critical Resources.

TABLE 3-1
PROPOSED MONITORING FEATURES AND FREQUENCIES

Critical Resource Area	Feature No.	Monitoring Features [1]		No.	Pre-Operational Monitoring Frequency			Operational Monitoring Frequency[2]									Post-Operational Monitoring Frequency		
								Recharge			Extraction			Storage					
					Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring
Springs in the Mojave National Preserve and BLM Managed Lands	1	S-Series Observation Wells [3] (2 to 3 per Cluster x 4 total Clusters)	New	4 clusters 8-12 wells	Continuous	Quarterly		Continuous	Annually	-	Continuous	Annually	-	Continuous	Annually		Continuous	Annually	
	2	Springs, Initial Characterization[4] (28+ total)	Existing	28+	-	-	One Time	-	-	-	-	-	-	-	-	-	-	-	-
	3	Springs, Monitoring (Approximately 8)[5]	Existing	8	Continuous at 2 Springs	One Time	Semi-Annually in Approximately 6 Springs	Continuous at 2 Springs	-	Semi-Annually in Approximately 6 Springs	Continuous at 2 Springs	-	Semi-Annually in Approximately 6 Springs	Continuous at 2 Springs	-	Semi-Annually in Approximately 6 Springs	Continuous at 2 Springs	-	Semi-Annually in 6 Springs
Aquifer System	4	Observation Wells (15 total)	Existing	12	Monthly	4 Quarterly, 8 Annually	-	Monthly for First 3 Months of Cycle; Annually Thereafter	Annually	-	Monthly for First 3 Months of Cycle	Annually	-	Monthly for First 3 Months of Cycle	Annually	-	Annually	Triannually	-
			Existing	2	Continuous	Annually	-	Continuous	Annually	-	Continuous	Annually	-	Continuous	Annually	-	Annually	Triannually	-
			New	1	Monthly	Quarterly	-	Monthly for First 3 Months of Cycle; Annually Thereafter	Annually	-	Monthly for First 3 Months of Cycle	Annually	-	Monthly for First 3 Months of Cycle	Annually	-	Annually	Triannually	-
	5	Project Area Well Clusters[7,8] - Unsaturated Zone Only (1 per Cluster x 3 total Clusters)	New	3 wells	-	-	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	-	-	-
	6	Project Area Well Clusters - Saturated Zone Only[8] (2 per Cluster x 3 total Clusters)	New	6 wells	Continuous	Quarterly	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous (Until No Longer Deemed Necessary)	Annually	-

TABLE 3-1
PROPOSED MONITORING FEATURES AND FREQUENCIES (CONTINUED)

Critical Resource Area	Feature No.	Monitoring Features [1]		No.	Pre-Operational Monitoring Frequency			Operational Monitoring Frequency[2]									Post-Operational Monitoring Frequency		
								Recharge			Extraction			Storage					
					Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring
	7	Production Wells (30 total)	Existing	4	-	-	-	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	-
			New	26	-	-	-	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	-
	8	Recharge Water Quality[8]	Existing	1	-	-	-	-	Weekly by MWD (Annually Title 22)	-	-	Weekly by MWD	-	-	Weekly by MWD	-	-	-	-
Aquifer System	9	Spreading Basins	New	1	-	-	-	-	-	Regular Basis	-	-	Summarize Data Monthly	-	-	Summarize Data Monthly	-	-	-
	10	Land Surface Elevation Surveys (22 total)	New Benchmark	20	-	-	Annually	-	-	Annually	-	-	Annually	-	-	Annually	-	-	-
			InSAR (New)	2/yr (If Warranted)	-	-	Semi-Annually	-	-	Annually	-	-	Semi-Annually	-	-	Annually	-	-	-
	11	Extensometer (if warranted) (1 total)	New	1	-	-	-	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	-
	12	Microgravity Stations (if warranted) (10 total)	New	10	-	-	One Time	-	-	Annually (if warranted)	-	-	Annually (if warranted)	-	-	Annually (if warranted)	-	-	Annually (until no longer deemed necessary)
	13	Flowmeter Surveys (5 total)	New	5	-	One Time	One Time	-	-	-	-	-	-	-	-	-	-	-	-
Bristol and Cadiz Dry Lakes	14	Bristol Dry Lake Well Clusters[10] (3 per Cluster x 3 total Clusters)	New	3 clusters 9 wells	Continuous	Quarterly	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous (until no longer deemed necessary)	Annually as necessary	-
	15	Cadiz Dry Lake Well Clusters[11] (3 per Cluster x 3 total Clusters)	New	3 clusters 9 wells	Continuous	Quarterly	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous	Semi-Annually	-	Continuous (until no longer deemed necessary)	Annually as necessary	-

TABLE 3-1
PROPOSED MONITORING FEATURES AND FREQUENCIES (CONTINUED)

Critical Resource Area	Feature No.	Monitoring Features [1]		No.	Pre-Operational Monitoring Frequency			Operational Monitoring Frequency[2]									Post-Operational Monitoring Frequency		
								Recharge			Extraction			Storage					
					Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring	Water Level	Water Quality	Other Monitoring
	16	ET Stations (Eddy Correlation-Type) (2 total)	New	2	-	-	Continuous	-	-	Continuous	-	-	Continuous	-	-	Continuous	-	-	-
	17	Surface Water Gages[12] (2 total)	New	2	Continuous	-	-	Continuous	-	-	Continuous	-	-	Continuous	-	-	-	-	-
Bristol and Cadiz Dry Lakes (cont.)	18	Nephelometer Open-Air[13] With Digital Camera (4 total)	New	4	-	-	Hourly	-	-	Hourly	-	-	Hourly	-	-	Hourly	-	-	-
	19	Resistivity Survey (1 total)	New	1	-	-	One Time	-	-	-	-	-	-	-	-	-	-	-	-
	20	Gamma / EM Logs (up to 6 total)	New	6	-	-	One Time	-	-	-	-	-	-	-	-	-	-	-	-
Other (Regional)	21	Weather Stations (4 total)	Existing	3	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	-
			New	1	-	-	Records Hourly	-	-	Records Hourly	-	-	Records Hourly	-	-	Records Hourly	-	-	-
	22	Stream Gages (3 total)	Existing	1	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	Records Daily	-	-	-
			New (if warranted)	2	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	-
	23	Soil Moisture Sensors (2 total)	New	2	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	Records Daily (if warranted)	-	-	-
	24	Meteorological Towers (2 total)	New	2	-	-	Records Hourly	-	-	Records Hourly	-	-	Records Hourly	-	-	Records Hourly	-	-	-
	Not Numbered	Transmissio-meter(s)[14] (If Warranted)			-	-	TBD	-	-	TBD	-	-	TBD	-	-	TBD	-	-	-

TABLE 3-1
PROPOSED MONITORING FEATURES AND FREQUENCIES (CONTINUED)

Notes:

1 See Table 3-2 for details of monitoring features.
2 Monitoring frequencies pertain to the initial monitoring period of Operational phase. Monitoring frequency may be increased or decreased based on the initial monitoring results.
3 Four well clusters: one to be installed in Orange Blossom Wash and three to be installed between the Project area and the Clipper Mountains (see Figure 3-4).
4 Identified springs will be field-investigated to determine site specific characterization which includes geology, hydrology, and vegetation characteristics.
5 To be determined by National Park Service.
6 To be monitored using a piezometer equipped with a pressure transducer in the immediate vicinity of the springs.
7 Well clusters will consist of 2 to 3 wells at the same location, screened (i.e. completed) at different intervals. (Note: Well Clusters in the recharge and extraction area will consist of 1 unsaturated zone monitoring well and 2 saturated zone monitoring wells).
8 Features 5 and 6 together comprise 3 total clusters. They have been separated on this table to more completely define the unsaturated and saturated zone monitoring.
9 Water quality samples of input to artificial recharge facilities (i.e. Colorado River Aqueduct water) will be taken from weekly measurements at Lake Havasu.
10 Two well clusters to be installed along the eastern margin of Bristol Dry Lake and one to be installed on Bristol Dry Lake. (Note: All 3 of the wells in these clusters will measure groundwater characteristics, i.e. water levels and quality).
11 Two well clusters to be installed along the northern margin of Cadiz Dry Lake and one to be installed on Cadiz Dry Lake. (See Note: under 9 above)
12 Surface water gages will measure depth of ponded storm water runoff at the ET stations on Bristol and Cadiz Dry Lakes.
13 Open air nephelometers measure light scattered by particles in the atmosphere at Bristol and Cadiz Dry Lakes.
14 Transmissometer(s) or other instrumentation as determined by the TRT would be installed at boundaries of Class I areas, if warranted.

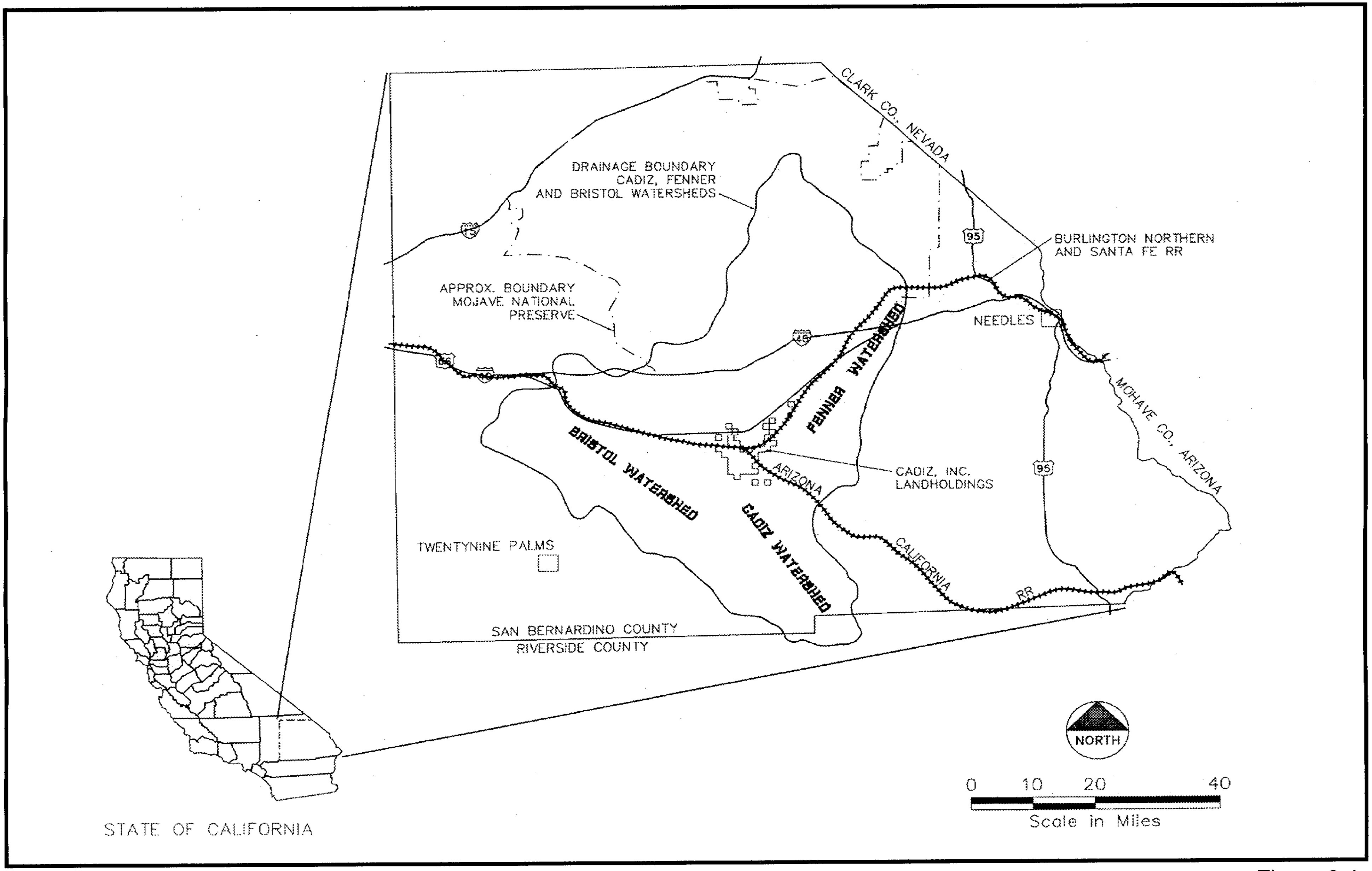


Figure 3-1

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Location of the Bristol, Cadiz, Fenner, and Orange Blossom Wash Watersheds

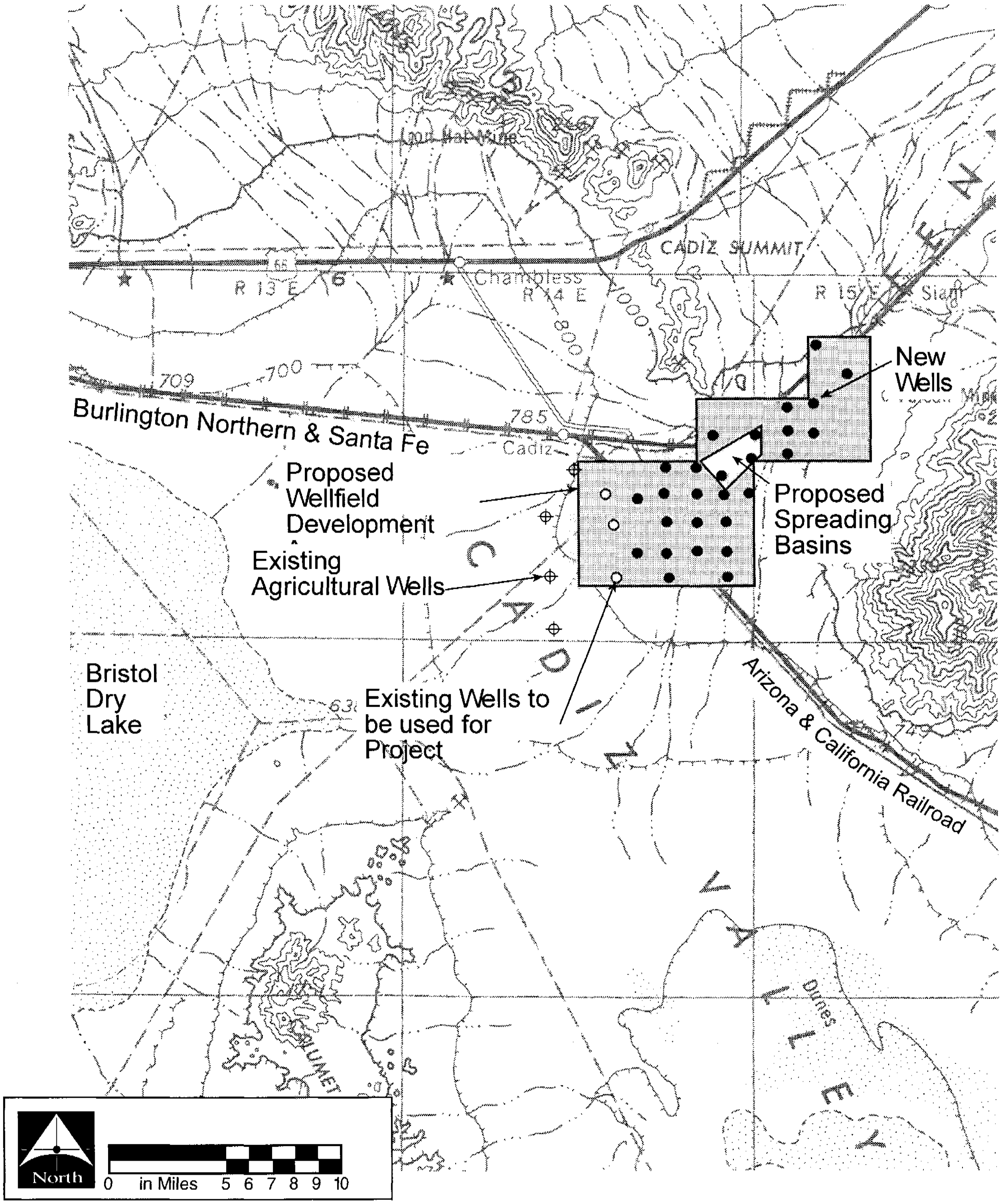


Figure 3-2

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Proposed Project Wellfield and Spreading Basins

The Cadiz Project would involve construction and operation of the facilities shown on Figures 3-2 and 3-3 and as described below:

Spreading basins and appurtenant facilities to be constructed on approximately 390 acres.

- A wellfield of approximately 30 extraction wells and appurtenant facilities.
- An approximately 35-mile-long conveyance pipeline and appurtenant facilities from the CRA to the project spreading basins and wellfield.
- A pumping plant on the conveyance pipeline, to be located in proximity to the Iron Mountain Pumping Plant.
- A power distribution system to be constructed generally parallel to the alignment of the conveyance pipeline.
- Instrumentation and control systems to monitor all project storage and extraction operations.
- Observation wells, cluster wells, land survey benchmarks, evapotranspiration stations, meteorological towers, a weather station and other appurtenant facilities necessary for the Management Plan.

With the exception of most of the conveyance and power distribution facilities, certain observation wells, survey benchmarks, and other monitoring features, all project facilities would be located on land owned by Metropolitan or Cadiz.

3.1.3 EXISTING GROUNDWATER BASIN MANAGEMENT

Cadiz owns more than 27,000 acres in the Cadiz and Fenner Valleys of eastern San Bernardino County as shown in Figure 3-1. Approximately 1,600 acres of this land have been developed for citrus and stone fruit orchards, vineyards, and specialty row crops.

In 1993, San Bernardino County certified a Final Environmental Impact Report (FEIR) and granted various land use approvals for expansion of agricultural operations on this property up to 9,600 acres. As a component of this approval, the County identified specific groundwater monitoring activities to be undertaken by Cadiz. To comply with these monitoring requirements, the Cadiz Valley Agricultural Development Ground Water Monitoring Plan (GWMP) was developed in cooperation with San Bernardino County to monitor all potential environmental impacts that could result from the agricultural irrigation. As a result of a Memorandum of Understanding (MOU) still in draft form between San Bernardino County, Metropolitan, and Cadiz, future groundwater use for irrigation in the project area would be subject to the provisions of the Management Plan. This Management Plan incorporates the key provisions of the GWMP.

3.1.4 PURPOSE AND SCOPE

The purpose of this Management Plan is to ensure protection of the Critical Resources in the Fenner, Bristol and Cadiz Valleys. For purposes of this Management Plan, project operations would be evaluated to

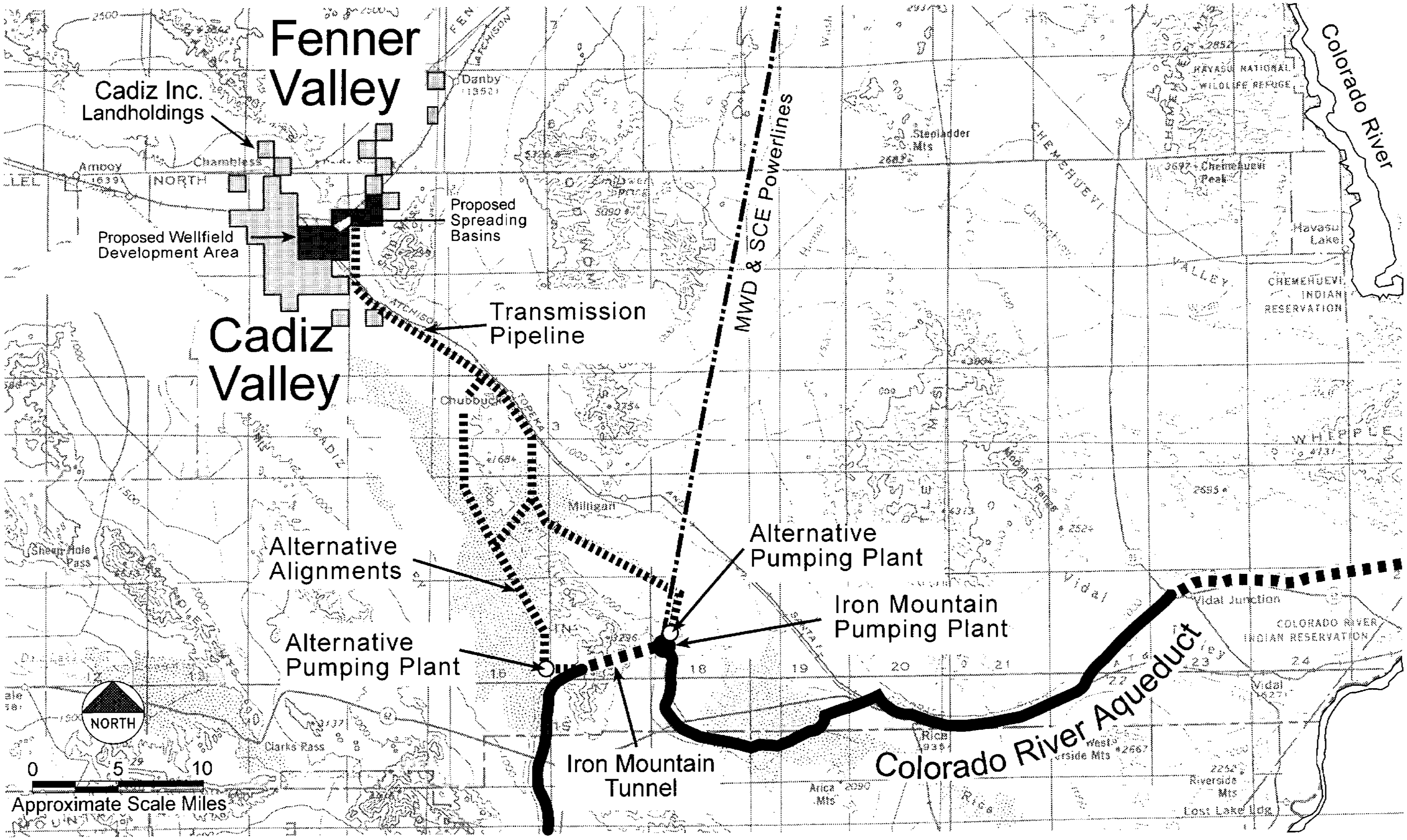


Figure 3-3

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Proposed Project Facilities

include the agricultural operations as outlined in the GWMP.

This Management Plan includes the following:

1) Description of the Cadiz Project location and objectives;

2) Identification of the Critical Resources and potential adverse impacts in and surrounding the project area due to project groundwater storage and extraction operations;

3) Description of the modeling tools that would be used to refine the monitoring network, and would be used, in the future, to refine Action Criteria;

4) Description of the monitoring network and identification of the conceptual locations of the features of the monitoring network;

5) Description of the monitoring, testing, and reporting procedures that would be used to collect and analyze data;

6) Description of the potential adverse impacts that may occur to the Critical Resources;

7) Description of the Action Criteria established to avoid potential adverse impacts;

8) Description of the decision-making process to be used once the Action Criteria are met;

9) Description of corrective measures that may be recommended by the TRT to prevent adverse impacts;

10) Description objectives and requirements for a Closure Plan; and

11) Description of the technical and management oversight groups (TRT and BMG), and their responsibilities and procedures.

3.2 CRITICAL RESOURCES AND POTENTIAL ADVERSE IMPACTS IN OR ADJACENT TO THE PROJECT AREA

This Management Plan addresses the following Critical Resources:

- Springs within the affected watersheds, including springs of the Mojave National Preserve and BLM-Managed Lands
- Aquifer System
- Brine Resources of Bristol and Cadiz Dry Lakes
- Air Quality in Joshua Tree National Park, Mojave National Preserve, and BLM-Managed Lands

Potential adverse impacts to these Critical Resources as a result of project operations are discussed below.

3.2.1 POTENTIAL IMPACTS TO SPRINGS WITHIN THE AFFECTED WATERSHEDS INCLUDING SPRINGS WITHIN THE MOJAVE NATIONAL PRESERVE AND BLM-MANAGED LANDS

- Potential for impact to spring flow within the Mojave National Preserve due to change of groundwater elevations as a result of project operations.

- Potential for impact to spring flow within designated BLM Wilderness Areas due to change of groundwater elevations as a result of project operations.

- Potential for impact to Bonanza Spring and all other springs located on BLM-managed lands within the affected watersheds of Bristol, Cadiz, Fenner and Orange Blossom Wash due to change in groundwater elevations as a result of project operations.

3.2.2 POTENTIAL IMPACTS OF THE PROJECT TO THE AQUIFER SYSTEM

For purposes of this Management Plan, the aquifer system includes aquifers of the Fenner, Bristol, and Cadiz basins. However, emphasis is placed on the aquifer system in the vicinity of the project area. The "project area" refers to the area encompassing the proposed artificial recharge facilities and extraction wellfield and is in and around the Fenner Gap area and existing Cadiz agricultural wellfield.

- Potential for impact to indigenous groundwater quality due to storage and extraction related to project operations.

- Potential for impacts to wells owned by neighboring landowners due to project operations.

- Potential for land subsidence and loss of groundwater storage capacity due to groundwater withdrawal.

- Potential for increased risk of liquefaction related to project spreading operations.

- Potential for hydrocompaction related to project spreading operations.
- Potential for induced flow of lower-quality water from Bristol and Cadiz dry lakes.

- Potential for long-term drawdown of groundwater.

3.2.3 POTENTIAL IMPACTS TO BRINE RESOURCES ON BRISTOL AND CADIZ DRY LAKES

- Potential for impacts to brine resources on Bristol and Cadiz dry lakes include:

  - Potential change in ground-water elevations impacting evaporation and brine concentrations.

  - Potential dilution of brine concentration from migration of relatively low total dissolved solids (TDS) concentration of stored water.

  - Potential introduction of non-native chemical constituents into brine water from migration of stored water.

3.2.4 POTENTIAL IMPACTS ON AIR QUALITY

Potential impacts to air quality including air quality impacts within the Mojave National Preserve, Joshua Tree National Park and BLM-managed lands due to mobilization of dust from changes in groundwater levels underlying Bristol and Cadiz dry lakes.

Under the Clean Air Act (CAA) Amendments of 1977, all existing international parks and national wilderness and wilderness areas greater than 5,000 acres in size were designated as "Class I areas". Class I areas are afforded greater protection of air quality and air quality related values (e.g. visibility). All other areas in the U.S. were designated as Class II areas under these amendments. Procedures were also provided in the CAA for States or Indian Tribes to reclassify Class II areas to either Class I or Class III (areas that would be provided less protection than Class II) status. The Mojave National Preserve is a Class II area, however, it is the stated goal of the NPS in its draft General Management Plan for the Mojave National Preserve (NPS, July 2000) to seek redesignation of the preserve as a Class I area.

Regardless of any Class I/Class II designation of parklands that are subject to potential adverse impacts to air quality any right-of-way granted by the BLM may include conditions necessary to ensure full compliance with the requirements of state or federal air pollution control laws and regulations, or otherwise protect the air quality related values (including visibility) of Joshua Tree National Park and Mojave National Preserve.

3.3 WATER-RESOURCES MODELS

A series of water-resource models would be developed and calibrated using available data during the Pre-Operational phase of the Cadiz Project under the guidance of the TRT (see Section 3.9 for a discussion of the TRT). The models would be refined and recalibrated as additional data are collected during the Operational phase of the project also under the guidance of the TRT. The TRT would review information and recommend appropriate models at the appropriate time contingent upon available data. For example, these may include a rainfall-runoff model, unsaturated and saturated zone flow models, solute-transport models, and a density dependent groundwater flow and solute-transport model.

Models are only approximations and simplifications of real systems. However, they can be useful management tools, when used in conjunction with measured data, for testing alternative monitoring designs and management options. Accordingly, these models would be used to help guide decisions on further evaluating and refining the monitoring network, and evaluating and refining Action Criteria.

The models discussed below are examples of models that may be recommended by the TRT to assist with their periodic review, analyses and recommendations. Although there are a number of models discussed below, the TRT will make final recommendations to the BMG as to which models would be necessary and appropriate for the Management Plan. On-going data collected during the term of the project, combined with the modeling tools, and recommendations from the TRT would assist the BMG in its review and resolution of issues.

As the responsible party, Metropolitan would prepare the water resource models with the guidance and review of the TRT.

3.3.1 DESCRIPTION OF WATER RESOURCES MODELS

3.3.1.1 Rainfall-Runoff Model

Rainfall-runoff models simulate the surface water balance and include parameters specific to the watershed, mean areal rainfall, interception, depression storage, infiltration, soil moisture storage, evapotranspiration, surface runoff, snowmelt runoff, interflow, groundwater baseflow, and channel routing. The rainfall-runoff models would be integrated with other models (e.g. groundwater flow and solute transport models).

Data input would include precipitation and evaporation data distributed as interception loss, rainfall on impervious areas (which contributes directly to runoff), and infiltration. Infiltration is either interflow, which moves through the upper soil zone to channel flow, or deep percolation, which is flow into the lower soil zone, which contributes to active or inactive groundwater storage. The rainfall-runoff model would be initially calibrated using the streamflow data collected during the Pre-Operational phase of the project.

3.3.1.2 Unsaturated Zone Flow and Transport Model

An unsaturated zone flow and transport model would be employed to simulate the movement of infiltrated water under the ephemeral stream channels as well as the project spreading basins. For the purposes of simulation, infiltration under an ephemeral stream would be treated as a line source and would initially be simulated as a two-dimensional process coincident with the stream. Lateral redistribution away from the stream would be simulated as a two-dimensional process perpendicular to the stream. This model (along with other models) would be utilized by the TRT in analysis and refinement of both the monitoring network and Action Criteria

The model input requires volumetric moisture content, moisture potential, porosity, unsaturated and saturated hydraulic conductivity data, and subsurface layering. These data would be estimated from soil cores collected during the Pre-Operational phase of the project. Unsaturated zone instrumentation would be installed, in accordance with TRT and BMG recommendations, to measure soil suction, pressure head, and water chemistry as the water percolates downward through the unsaturated zone to the water table. Neutron and electromagnetic logs may be used to collect data at selected well sites to monitor the movement of the recharge "wetting" front if warranted through further evaluation and recommendation by the TRT and the BMG. Data collected from the instrumentation would be used to help recalibrate the model when Colorado River water is delivered into the project spreading basins.

3.3.1.3 Saturated Zone Flow and Transport Model

A numerical groundwater flow and solute transport model would be developed and calibrated to better understand the dynamics of groundwater flow and solute transport in the project area. The domain of the groundwater flow and transport model would include the Bristol, Cadiz, Fenner and Orange Blossom Wash watershed. This model along with other models would be utilized by the TRT in analysis and refinement of both the monitoring network and Action Criteria.

A conceptual model would first be developed incorporating the area of interest, aquifer systems to be modeled and boundary conditions. It is understood that the conceptual model would be predicated upon a thorough analysis of the available geohydrologic data for the area. Only after a conceptual model is developed can the numerical models be developed. Development of the numerical models requires information on: (1) the aquifer geometry; (2) rate and quality of groundwater inflow and outflow; and (3) aquifer characteristics (hydraulic conductivity, saturated thickness, effective porosity, specific storativity, dispersivity, retardation and leakance). The groundwater flow model would integrate quantities and distribution of recharge estimated from the rainfall-runoff and unsaturated zone models.

3.3.1.4 Density Dependent Groundwater Flow and Transport Model

To assist the TRT in providing technical guidance on groundwater management issues, density dependent flow and transport models would be developed near both Cadiz and Bristol dry lakes. The models would simulate the transport of solute mass through numerical solution of a mass balance equation involving fluid density. The single solute species could be transported conservatively, or it could undergo sorption. Sources and boundary conditions of fluid and solute would be specified at the upgradient boundary of the model.

The model domain would extend outward from the project spreading basins to Bristol and Cadiz dry lakes. The area of interest for the model grid would be determined by further evaluation but would probably extend several miles. The height, and horizontal and vertical grid spacing would be selected based on available data and the intended use of the models by the TRT. These models include hydraulic conductivity, specific storativity, effective porosity, and dispersion coefficients for each model element. Specified flux and chloride mass fraction would be provided by the regional groundwater flow and solute transport model described previously.

3.3.2 EVALUATION OF POTENTIAL ADVERSE IMPACTS USING NUMERICAL MODELS

The water resource models (rainfall-runoff, unsaturated flow and transport, and density dependent flow and transport) developed during the Pre-Operational phase of the project would be used to simulate the impacts of planned project operations. The results of the simulations would be used by the TRT to evaluate and refine Action Criteria and the monitoring network. Models would also be used to simulate potential impacts for feasible project operations (including Cadiz agricultural operations) within the estimated ranges of natural recharge (low and high estimates). Evaluation of the model results could result in recommendations to the BMG to refine Action Criteria as well as identifying areas where collection of additional data would be needed to improve the monitoring network.

3.3.2.1 Evaluation of Variable Recharge Estimates and Long-Term Impacts

It is recognized that there is uncertainty regarding the quantity of natural recharge as well as ground water travel times from areas of recharge to areas of discharge. The models would be run for various operational scenarios using a range of natural recharge estimates. The put (artificial recharge) and take (extraction) cycles would be tested for the range of natural recharge estimates to evaluate the sensitivity of the aquifer system, the Action Criteria, and the monitoring network to low and high estimates of natural recharge. Impacts from the project could have delayed effects which could persist after the termination of the project. Therefore, the project operation (put and take cycles) would be simulated with different natural recharge characteristics into the future until simulated water-level and water-quality changes approach a steady state condition. These models will enable members of the TRT and BMG to evaluate the potential for adverse impacts and protect Critical Resources during the Operational and Post-Operational phases and well into the future.

3.3.2.2 Model Refinement and Multi-Year Predictions

During the term of the project, new data and analysis as well as any new project operational considerations would be used to refine the calibration of the various water resource models. This model refinement would take place approximately every two years, or as otherwise recommended by the TRT and the BMG. The refined models would be used to provide five-year predictions based on the current stage of the project (or as recommended by the TRT and the BMG). For example, a five-year prediction should be simulated before the first "put" cycle. Two years into the "put" cycle the model should be refined based on the new data and analysis to produce another five-year prediction.

The models would be a necessary part of the Management Plan and provide input to the decision-making process. These model results would assist the TRT with its periodic analyses of monitoring data and Action Criteria, and for example, show how the system might respond under the varying natural recharge conditions. On-going data collected during the Operational phase combined with the predictive modeling tools would help to resolve project-related issues. If, for example, the "take" cycle caused a one-foot decline in an S-Series well (an observation-well cluster located upgradient of the project wellfield), and the decision was made to modify project operations, this management decision could then be simulated with the model to predict how long it may take for the system to recover assuming different natural recharge rates. Modifications of project operations could include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of ground-water extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

3.4 AIR QUALITY ANALYSES RELATED TO MOBILIZATION OF LAKEBED DUST

3.4.1 AIR QUALITY MONITORING AT BRISTOL AND CADIZ DRY LAKES

The water resources models discussed above would be integrated to interpret groundwater level data at locations between the project area and dry lakes, dry lake margins and beneath the dry lake beds gathered by the monitoring wells. This modeling allows evaluations to be made so that, if necessary, appropriate modifications can be made to the Cadiz Project operations so that the project does not cause groundwater level declines beneath the surface of the dry lakes which would contribute to or cause an increase in the mobilization of dust from the surface of the dry lake beds.

Well clusters on the dry lakes would be aligned with well clusters at the dry lake margins and monitoring wells closer to the immediate project area. This configuration of observation wells would provide a series of early warning monitoring locations. This information, together with the monitoring and analysis of other groundwater and meteorological information would be used to manage project operations to ensure that any water level changes beneath the surface of the dry lakes attributable to project operations would not cause an increase in the mobilization of dust from the surface of the dry lakes. Groundwater flow models, including density dependent models at the dry lakes, would also be used to predict potential impacts to groundwater levels and potential for dust mobilization due to project operations.

Additionally, lake bed surface soil moisture and evapotranspiration would be monitored. Air quality instrumentation (open-air nephelometers) and weather stations would be installed on each dry lake bed to obtain continuous data on dust mobilization and wind speed and direction. Analysis of mobilization and wind data would indicate whether there is any changing relationship between these two factors (reduced wind speed required for dust mobilization). This dust/wind speed relationship would also be compared with any changes in surface soil moisture of the dry lake beds and groundwater levels beneath the dry lake beds.

Monitoring features 4, 6, and 13 through 17 discussed in section 3.5 would be used in the groundwater models to provide predictive analysis and avoidance of potential increased dust mobilization from Bristol and Cadiz dry lakes as a result of the Cadiz Project.

Meteorological data (Section 2.4.7) indicates that the highest wind speeds are associated with winds from the west-northwest, west and southwest. Therefore, open-air nephelometers would be located at the western and eastern edges of Bristol Dry Lake, which would be expected to be at upwind and downwind locations of the lake bed during high-wind periods. The downwind open-air nephelometer would detect high concentrations of wind-mobilized particulate matter from the lake bed, while the upwind open-air nephelometer would identify region-wide dust storms. Solar-powered open-air nephelometers would be used. The open-air nephelometers would measure large increases in light scattering associated with dust storms. Additionally, an automated digital camera would be located to provide periodic photographs of the lake bed as further documentation of the occurrence of dust mobilization from the lake.

Meteorological data in the vicinity of Cadiz Dry Lake are not available. However, it is believed likely that the mountains that lie to the east and the west of the dry lake channel wind flow, leading to predominantly northwesterly and southeasterly winds. Therefore, open-air nephelometers would be located at the northern end of the lake bed, in the vicinity of the new cluster wells to be installed there, and at the southern end of the lake. An automated digital camera would also be located to provide periodic photographs of the lake bed as further documentation of the occurrence of high concentrations of wind-mobilized particulate matter from the lake. Data from the open-air nephelometers would be analyzed in tandem with wind velocity and direction information obtained from the weather stations on Bristol and Cadiz dry lakes included as part of Feature 16.

Placement of the open-air nephelometer locations at Bristol and Cadiz dry lakes would be reviewed by the TRT, and adjustments made should the meteorological data indicate that they are not located at appropriate upwind or downwind locations.

3.4.2 AIR QUALITY MONITORING AT CLASS I AREA

Additionally, there are questions regarding the potential for any project-mobilized dust from Bristol or Cadiz dry lakes to contribute to degradation of visibility within Class 1 areas designated by the Clean Air Act (currently applies to Joshua Tree National Park, but would also apply to Mojave National Preserve if it is designated as a Class I area). This issue would be addressed in two stages. Stage 1 would have a duration of five years beginning in the Pre-Operational phase of the project and extending into the initial years of the project Operational phase. During this period of five years, two meteorological towers would be installed in the region under the guidance of the TRT to measure wind speed and direction (see Section 3.5.4). The TRT may recommend that this period be shortened, should it be determined earlier that there is a potential for any project-mobilized dust to be transported to a Class I area.

This baseline information would be used in conjunction with lakebed data for groundwater levels and soil moisture to determine whether (a) the project could contribute to lakebed dust mobilization and (b) if any project-mobilized lakebed dust could be transported into a Class I area. This review would consider whether existing dust storms on the dry lake beds occur simultaneously with regional winds that are capable of transporting lakebed dust into a Class I area. If these analyses conclude that there is not a potential for project-mobilized dust to reach the Class I area, stage 2 of this analysis would not be implemented. If the potential is determined to exist, then the TRT would recommend the implementation of stage 2.

Stage 2 would require the placement of instrumentation at the boundary of the Class I area at a location most likely to detect project-mobilized lakebed dust. The specification and location for placement of instrumentation would be recommended by the TRT utilizing wind and other pertinent data obtained during Stage 1. The TRT would recommend a study design and use of appropriate instrumentation and data collection protocols to monitor potential changes in visibility and to determine whether such changes are attributable to the project. It is anticipated that a transmissometer would be utilized to gather visibility data and would be installed early in the 50-year Operational phase of the project in order to establish baseline visibility conditions. Changes to the baseline would be reviewed by the TRT in conjunction with other appropriate data (per the study design) to determine whether such change in visibility is the result of any project-mobilized dust.

3.5 MONITORING NETWORK

The development of the monitoring network would involve a "phased approach." Integral with the phased approach would be the development and refinement of a number of water resource models as described in Section 3.3. Under the guidance of the TRT, the Management Plan would be implemented with an initial set of monitoring features and parameters developed from the existing data. As new data become available, the monitoring features defined below would be refined as necessary to protect Critical Resources in and adjacent to the project area.

A total of 24 different monitoring features have been identified for assessing potential impacts to the four Critical Resources during the term of the Cadiz Project. As described in Section 3.2, these Critical Resources include springs located within the Mojave National Preserve and BLM-Managed Lands, the aquifer system, and Bristol and Cadiz dry lakes as relates to brine resources and air quality associated with dust mobilization from Bristol and Cadiz dry lakes. A summary of the types of monitoring features, as well as monitoring frequencies, is provided in Table 3-1. A detailed list of each monitoring feature is provided in Table 3-2. Generalized locations are shown in Figures 3-4 and 3-5.

Installation of certain monitoring features would be subject to site-specific approval and permitting by applicable regulatory agencies. If the implementation of monitoring features currently contained in Management Plan were not approved, the TRT would evaluate and recommend alternate monitoring sites.

The following text describes in detail the various proposed monitoring features.

Proposed "S-Series" Observation Wells (Feature 1)

A series of "early-warning" observation wells known as the "S-Series" wells would be established to monitor groundwater-level fluctuations in the project aquifer system, in order to detect any impacts to the aquifer system due to project operations before such impacts reach the boundary of the Mojave National Preserve. Water-level fluctuations in these observation wells would act as an "early warning" measure of potential adverse impacts that might extend to springs in the Mojave National Preserve or BLM-managed lands in the affected watersheds.

Four S-Series observation-well clusters would be established upgradient of the project wellfield and spreading basins which are approximately equidistant between (1) the project wellfield and spreading basins and (2) the boundary of the Mojave National Preserve. One S-Series observation-well cluster would be established in each of the following four general locations, as shown on Figure 3-4: (1) in Orange Blossom Wash; (2) in Clipper Wash (between the Marble Mountains and the Clipper Mountains); (3) directly south of the Clipper Mountains (generally south of Bonanza Spring); and (4) in Schulyler Wash. Each S-Series observation-well cluster would consist of two or three separate well casings installed within their own individual boreholes, and completed and screened at different depths including wells screened in the production aquifer(s) and one screened across the water table. These well clusters would be used to provide information regarding potentiometric head and water quality with depth.

A typical observation well cluster completion is illustrated on Figure 3-6. Screened intervals for each of the wells within each cluster would be determined from logging of cuttings and geophysical logging of the deep borehole which would be drilled first. Each deep well would be completed with PVC or other suitable well casing and screen to allow for dual induction geophysical logging (see Section 3.4). Shallow and intermediate wells would be completed with PVC or other suitable well casing and screen.

All new observation well drilling and well installation would be conducted in accordance with the protocols specified in ASTM D5092-90 (see Appendix A). During drilling, selected core intervals would be collected and classified from the borehole for each of the deepest cluster

TABLE 3-2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Springs in the Mojave National Preserve and BLM Managed Lands	1	S-Series Well Clusters[b] (2 to 3 per Cluster x 4 total Clusters)	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Section 3.6.1	See Appendices C & D	-
			Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Section 3.6.1	See Appendices C & D	-
			Pre-Operational Operational Post-Operational	TBD	TBD[c]	TBD	Transducer, See Section 3.6.1	See Appendices C & D	-
			Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Section 3.6.1	See Appendices C & D	-
	2	Initial Spring Survey (28+ total)	Pre-Operational	TBD	NA[d]	TBD	-	See Section 3.6.1 and Appendix D	See Section 3.6.1
	3	Springs, Monitoring (8 total)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	Transducer, See Section 3.6.1	-	See Section 3.6.1
Aquifer System	4	Observation Well	Pre-Operational Operational	New Well	5N/14E-31L2	TBD	Transducer, See Sections 3.5 and 3.6.2	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Dormitory	5N/14E-5F1	34° 32' 38" N 115° 31' 57" W	Transducer, See Sections 3.5 and 3.6.2	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	6/15-29	6N/15E-29P1	34° 34' 20" N 115° 26' 04" W	Transducer, See Sections 3.5 and 3.6.2	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-11	5N/14E-13R1	34° 25' 52 N 115° 27' 25" W	Transducer, See Sections 3.5 and 3.6.2	See Appendices C & D	-

TABLE 3-2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Aquifer System	4	Observation Well	Pre-Operational Operational	CI-3	5N/14E-24D2	34° 30' 40" N 115° 28' 01" W	Transducer, See Sections 3.5 and 3.6.2	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Archer Siding #1	4N/15E-24E1	34° 25' 11" N 115° 21' 57" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Essex	8N/17E-31	34° 43' 49" N 115° 14' 53" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Fenner	8N/17E-2	34° 48' 59" N 115° 10' 40" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Goffs	10N/18E-26	34° 54' 57" N 115° 03' 44" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	Labor Camp	5N14E-16H1	34° 31' 22" N 115° 30' 46" W	Transducer, See Section 5.2.1.1	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-5	5N/14E-31L1	34° 28' 38" N 115° 33' 09" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-9	5N/13E-14B1	34° 31' 36" N 115° 35' 18" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-10	5N/14E-34Q1	34° 28' 11" N 115° 30' 03" W	Manual, See Appendix B	See Appendices C & D	-
		Observation Well	Pre-Operational Operational	SCE-17	5N/15E-29B1	34° 29' 45" N 115° 31' 57" W	Manual, See Appendix B	See Appendices C & D	-

TABLE 3-2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Aquifer System	4	Observation Well	Pre-Operational Operational	SCE-18	5N/13E-11R1	34° 26' 34" N 115° 34' 52" W	Manual, See Appendix B	See Appendices C & D	-
	5	Project Area Well Clusters[c]-Vadose Only (1 per Cluster x 3 total Clusters)	Operational	TBD	TBD	TBD	Manual, See Appendix B	See Appendices C & D	-
	6	Project Area Well Clusters[c]-Groundwater (2 per Cluster x 3 total Clusters)	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 3.5 and 3.6.2	See Appendices C & D	-
	7	Existing Production Wells (4 total)	Operational	PW-1	5N/14E-24D1	34° 30' 41" N 115° 27' 53" W	-	-	See Sections 3.5 and 3.6.2
			Operational	22	5N/14E-22K1	34° 30' 21" N 115° 29' 01" W	-	-	See Sections 3.5 and 3.6.2
			Operational	27N	5N/14E-27B1	34° 29' 54" N 115° 29' 59" W	-	-	See Sections 3.5 and 3.6.2
			Operational	27S	5N/14E-27Q1	34° 28' 14" N 115° 29' 59" W	-	-	See Sections 3.5 and 3.6.2
	7	New Production Wells (26 total)	Operational	TBD	TBD	TBD	-	-	See Sections 3.5 and 3.6.2
	8	Recharge Water Quality	Operational	Lake Havasu	NA	TBD	-	See Sections 3.5 and 3.6.2	-

TABLE 3-2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Aquifer System	9	Spreading Basins	Operational	Fenner Gap	NA	TBD	See Sections 3.5 and 3.6.2	-	-
	10	Benchmark Stations (20 total)	Pre-Operational Operational	TBD	NA	TBD	-	-	See Sections 3.5 and 3.6.2
		InSAR (2 per year)	Pre-Operational Operational	NA	NA	NA	-	-	See Sections 3.5 and 3.6.2
	11	Extensometer (if warranted) (1 total)	Operational	TBD	NA	TBD	-	-	See Sections 3.5 and 3.6.2
	12	Microgravity Stations, if warranted (10 total)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	See Sections 3.5 and 3.6.2	-	-
	13	Flowmeter Surveys (5 total)	Pre-Operational	TBD	TBD	TBD	-	-	See Sections 3.5 and 3.6.2
Bristol and Cadiz Dry Lakes	14	Bristol Dry Lake Well Cluster[f]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 3.5 and 3.6.3	See Appendices C & D	-
		Bristol Dry Lake Well Cluster[f]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 3.5 and 3.6.3	See Appendices C & D	-
		Bristol Dry Lake Well Cluster[g]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 3.5 and 3.6.3	See Appendices C & D	-
	15	Cadiz Dry Lake Well Cluster[h]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 3.5 and 3.6.3	See Appendices C & D	-
		Cadiz Dry Lake Well Cluster[h]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 3.5 and 3.6.3	See Appendices C & D	-

TABLE 3-2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
Bristol and Cadiz Dry Lakes	14	Cadiz Dry Lake Well Cluster[i]	Pre-Operational Operational Post-Operational	TBD	TBD	TBD	Transducer, See Sections 3.5 and 3.6.3	See Appendices C & D	-
	16	ET Station (Bristol Dry Lake)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	-	-	See Sections 3.5 and 3.6.3
		ET Station (Cadiz Dry Lake)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	-	-	See Sections 3.5 and 3.6.3
	17	Staff Gage (Bristol)	Pre-Operational Operational	TBD	NA	TBD	See Sections 3.5 and 3.6.3	-	-
		Staff Gage (Cadiz)	Pre-Operational Operational	TBD	NA	TBD	See Sections 3.5 and 3.6.3	-	-
	18	Nephelometers with Digital Cameras (4 total)	Pre-Operational Operational Post-Operational	TBD	NA	TBD	-	-	See Sections 3.5 and 3.6.3
	19	Resistively Survey (1 total)	Pre-Operational	NA	NA	TBD	-	-	See Sections 3.5 and 3.6.3
	20	Gamma/EM Logs (up to 6 total)	Pre-Operational	TBD	TBD	TBD	-	-	See Sections 3.5 and 3.6.3
Other (Basin-wide)	21	Weather Station	Pre-Operational Operational	Amboy	NA	34° 31' 52" N 115° 41' 42" W	-	-	See Sections 3.5 and 3.6.4
		Weather Station	Pre-Operational Operational	Mitchell Caverns	NA	34° 56' 06" N 115° 30' 58" W	-	-	See Sections 3.5 and 3.6.4
		Weather Station	Pre-Operational Operational	Fenner Gap	NA	TBD	-	-	See Sections 3.5 and 3.6.4

TABLE 3-2
SUMMARY OF MONITORING FEATURES AND PROTOCOLS (Continued)

Critical Resource Area	Feature No.	Feature Type	When Monitored	Name	State Well Number	Location Coordinates[a]	Monitoring Protocol		
							Water Level	Water Quality	Other Monitoring
		Weather Station	Pre-Operational Operational	TBD	NA	TBD	-	-	See Sections 3.5 and 3.6.4
Other (Basin-wide)	22	Stream Gage	Pre-Operational Operational	Caruthers Canyon	NA	35° 14' 42" N 115° 17' 53" W	-	-	See Sections 3.5 and 3.6.4
		New Stream Gages (2 total)	Pre-Operational Operational	TBD	NA	TBD	-	-	See Sections 3.5 and 3.6.4
	23	Soil Moisture Sensors (2 total)	Operational	TBD	NA	TBD	-	-	See Sections 3.5 and 3.6.4
	24	Meteorological Towers (2 total)	Pre-Operational Operational	Orange Blossom Wash & Un named Valley	NA	TBD	-	-	See Sections 3.5 and 3.6.4
	Not Numbered	Transmissometer(s)	Operational	TBD	NA	TBD	-	-	See Sections 3.5 and 3.6.4

NOTES:

a – Location coordinates to be verified in the field during initial Pre-Operational activity.

b – Four S-Series well clusters: one to be installed in Orange Blossom Wash and three to be installed between the project area and the Clipper Mountains.

c - To Be Determined.

d – Not Applicable.

e – Three new well clusters to be installed within project area.
Each cluster will consist of 2 groundwater monitoring wells and 1 unsaturated zone monitoring well.

f – Two new well clusters to be installed at eastern margin of Bristol Dry Lake.

g – One new well cluster to be installed on Bristol Dry Lake.

h – Two new well clusters to be installed north of Cadiz Dry Lake.

i – One new well cluster to be installed on Cadiz Dry Lake.

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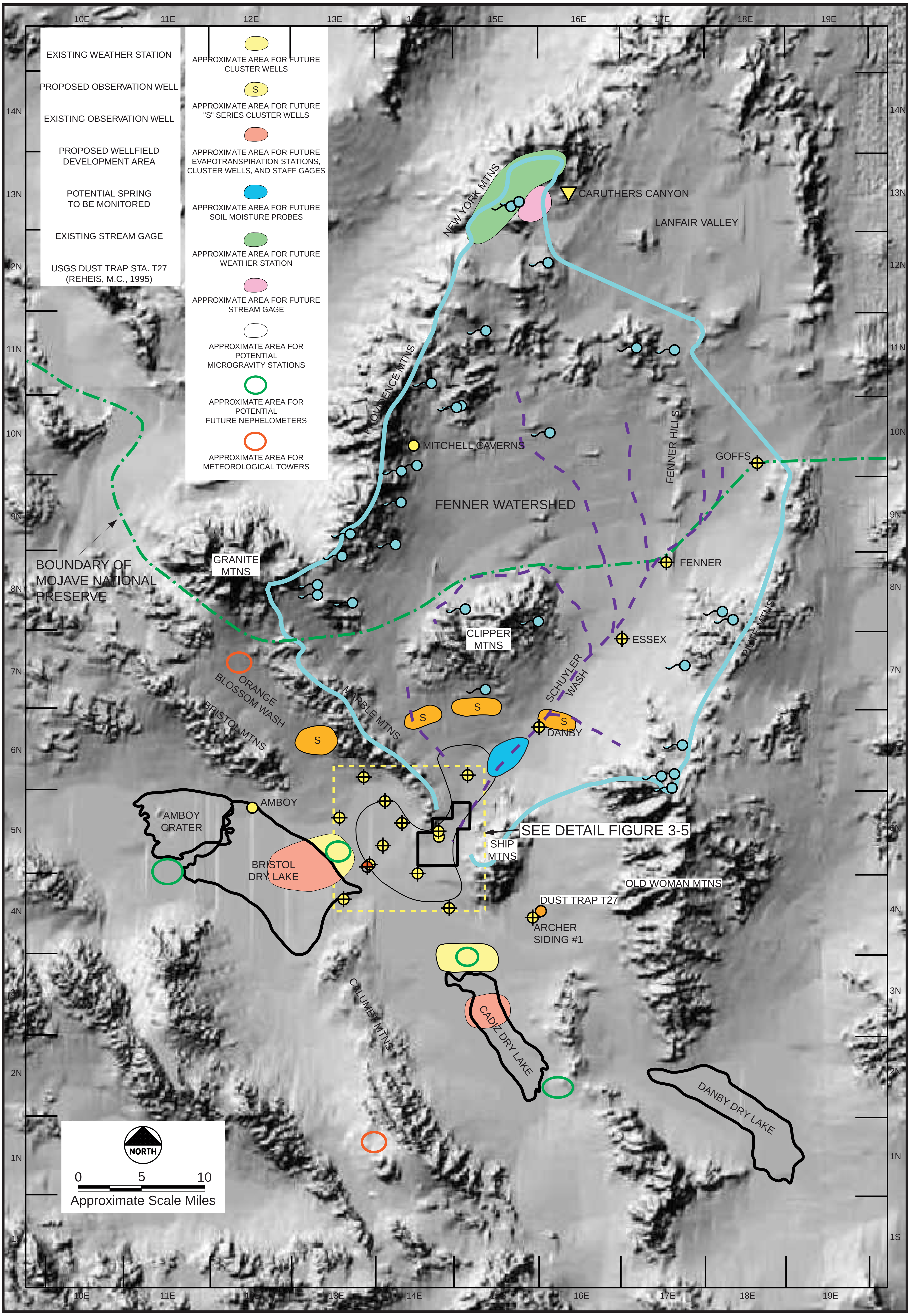

Figure 3-4

Cadiz Groundwater Storage & Dry-Year Supply Program

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Monitoring Features (Regional)

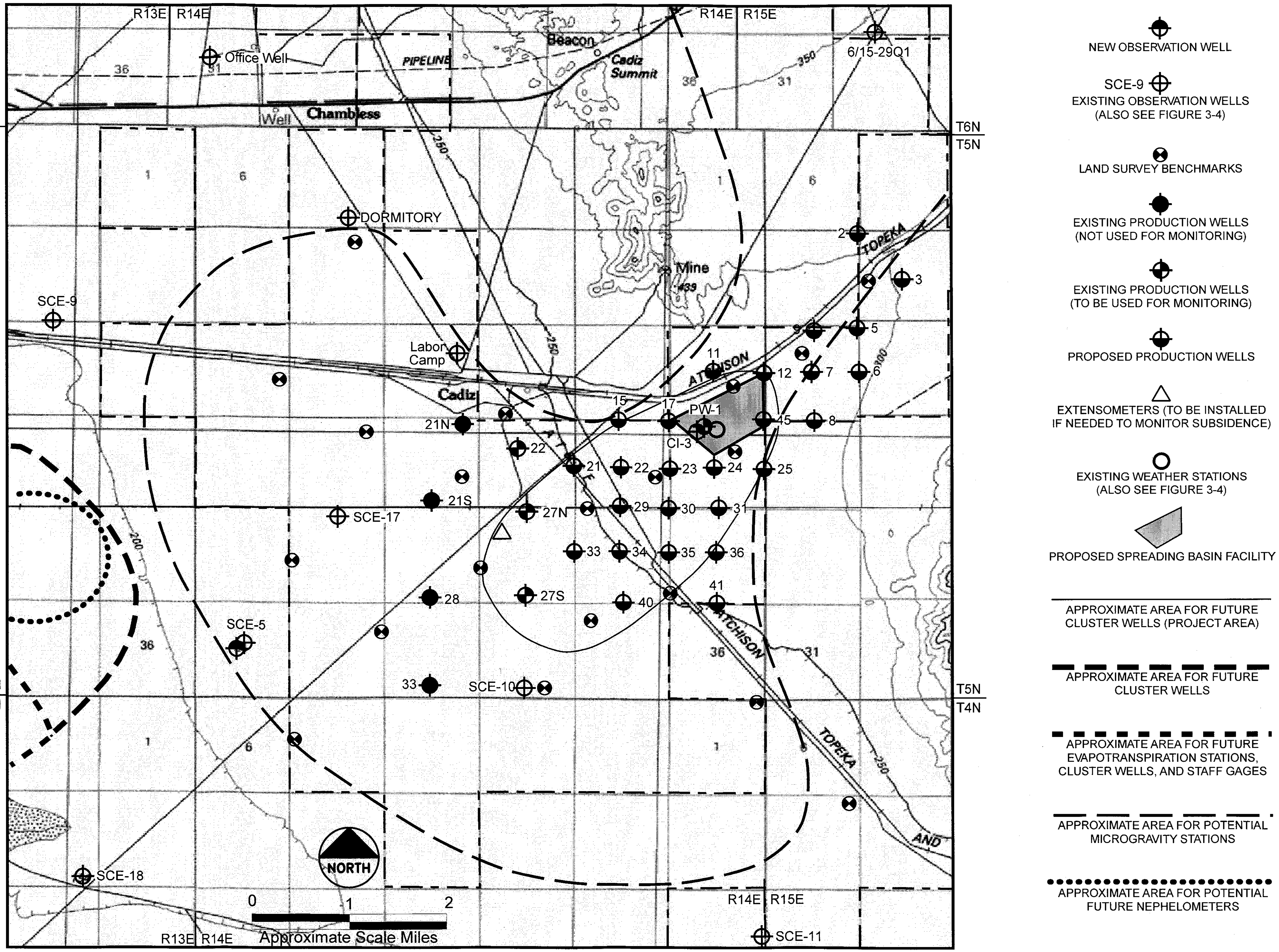

Figure 3-5

Cadiz Groundwater Storage & Dry-Year Supply Program

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Monitoring Features (Detail of Project Area)

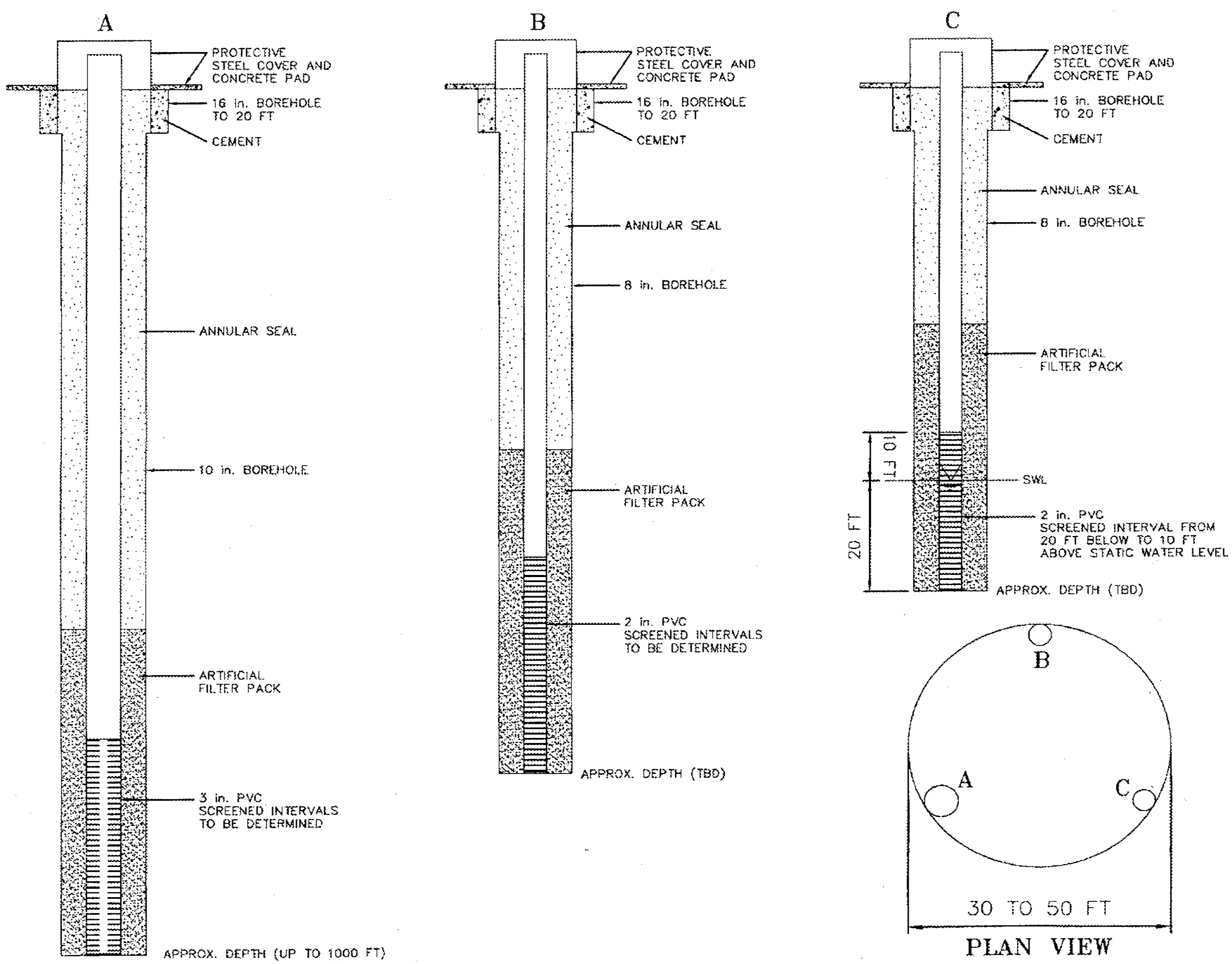

Figure 3-6

Cadiz Groundwater Storage & Dry-Year Supply Program

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Typical Observation Well Cluster Cross Section

wells. All soil samples would be classified in the field according to the Unified Soil Classification System (USCS). Selected cores would be submitted to a State certified laboratory for analysis of vertical permeability by ASTM D5084.

Springs (Features 2 and 3)

An inventory of 28 known springs within the Fenner and Orange Blossom Wash watersheds would be prepared in cooperation with the agencies within the Department of the Interior, as described in Section 3.5. During the term of the Cadiz Project, approximately eight springs would be selected as long-term monitoring sites, as described in Section 3.5. Likely long-term monitoring sites include: (1) one spring site on the south side of the Granite Mountains (e.g. Budweiser Spring, Willow Spring Basin, or Cove Spring); (2) one spring in the Van Winkle Mountains (Van Winkle spring); (3) one spring on the east side of the Providence Mountains (e.g. Quail spring or Foshay spring); (4) one spring on the south side of Wild Horse Mesa (most likely Whiskey spring); (5) one spring on the east side of the Fenner Valley within the Mojave National Preserve (probably Vontrigger spring); (6) Bonanza spring on the south side of the Clipper Mountains; (7) one spring in the Clipper Mountains Wilderness Area (e.g. Hummingbird spring), and (8) one spring in the Old Woman Wilderness Area (e.g. Barrel spring).

Observation Wells (Features 4 through 6)

A total of 14 existing observation wells would be used to monitor groundwater levels during the project (see Tables 3-1 and 3-2). Locations of these wells are shown on Figures 3-4 and 3-5. Six of these wells were installed in the 1960's by Southern California Edison as part of a regional investigation (wells whose designation begins with "SCE"). Three of the observation wells (Labor Camp, Dormitory, and 6/15-29) are owned and monitored by Cadiz as part of their agricultural operation. Well CI-3 was installed in Fenner Gap during the pilot spreading basin test for the project. Wells at Essex, Fenner, Goffs, and Archer Siding #1 are related to railroad operations or municipal supply. Wells would be utilized provided that appropriate permission and approval were obtained.

The project would incorporate 14 existing and 1 new (to be installed) observation[2] wells for the purposes of monitoring groundwater levels and collecting water quality samples in the vicinity of the project. Two different types of observation wells would be monitored: existing single completion observation wells and proposed multiple completion cluster wells. A total of 14 existing observation wells (each consisting of a single cased well with one screened interval) would be used as monitoring wells during the project. One new deep observation well would be installed adjacent to existing Observation Well SCE-5. A total of three new observation well clusters would be installed in the immediate project vicinity and monitored during the project[3].

2 Installation of any new monitoring facilities would be subject to approval by the applicable regulatory agencies.

3 Tables 3-1 and 3-2 separate features 5 and 6 to indicate that monitoring would occur in both the unsaturated and saturated zones. However, features 5 and 6 together total 3 clusters (not 3 clusters for each feature).

Proposed Observation Well Clusters Within the Immediate Project Area (Features 5 and 6)

Three well clusters would be established in the immediate vicinity of the project spreading basins and wellfield (see Figure 3-5). The uppermost screened interval of each cluster location would be above the Pre-Operational static water table (in the saturated zone of the future storage mound) to enable monitoring of elevated total dissolved solids water that would result from the leaching of salts out of the unsaturated zone during the initial infiltration of Colorado River water. The middle and lower screened intervals would be in the upper and lower aquifers, respectively. One well cluster would be developed around existing well CI-3, which is screened in the upper aquifer.

Project Production Wells (Feature 7)

Existing Cadiz Agricultural Wells

The Cadiz agricultural operation owns and operates seven agricultural wells used for irrigation, which are located west and southwest of the project spreading basins (see Figure 3-2). Three of the seven Cadiz irrigation wells could to be incorporated into the project wellfield (Wells 22, 27N, and 27S). In addition, one production well (PW-1) has already been constructed as part of the pilot spreading basin test and is located in the vicinity of the proposed project spreading basins.

New Production Wells

The project wellfield would consist of approximately 26 additional production wells to be located as shown on Figure 3-2. Each new well would be completed to a depth of about 1,000 feet (see Figure 3-7). The total capacity of the wellfield would range from 200 to 250 cfs.

Recharge Water Quality (Feature 8)

Delivery of Colorado River water to the project spreading basin facilities would be recorded from totalizer readings of flow at the Iron Mountain Pumping Plant. During operation of the project spreading basins, analyses of Colorado River water quality would be conducted on a weekly basis from samples collected at Lake Havasu.

Spreading Basins - Water Level Staff Gages (Feature 9)

Calibrated water level staff gages would be placed in each subbasin of the project spreading basin. Each staff gage would be located on the floor of the basin but close enough to the berm slope so as to be readable from the top of the berm.

Land Surface Monitoring (Feature 10)

A network of approximately 20 survey benchmarks would be installed at the approximate locations shown on Figure 3-5 to monitor changes in land surface elevation should they occur. Each benchmark would be established and surveyed by a California licensed land surveyor. All locations would be dependent upon permitting from the appropriate agencies. Benchmark surveys would be conducted on an annual basis during the term of the Cadiz Project (see Table 3-1).

If recommended by the TRT and the BMG, Pre-Operational baseline Interferometric Synthetic Aperture Radar ("InSAR")[4] data

[4] InSAR measures changes in the distance between the radar antenna and the land surface with an accuracy of +/- 2 to 4 mm (0.08 to 0.16 inches) (Amelung, et al., 1999).

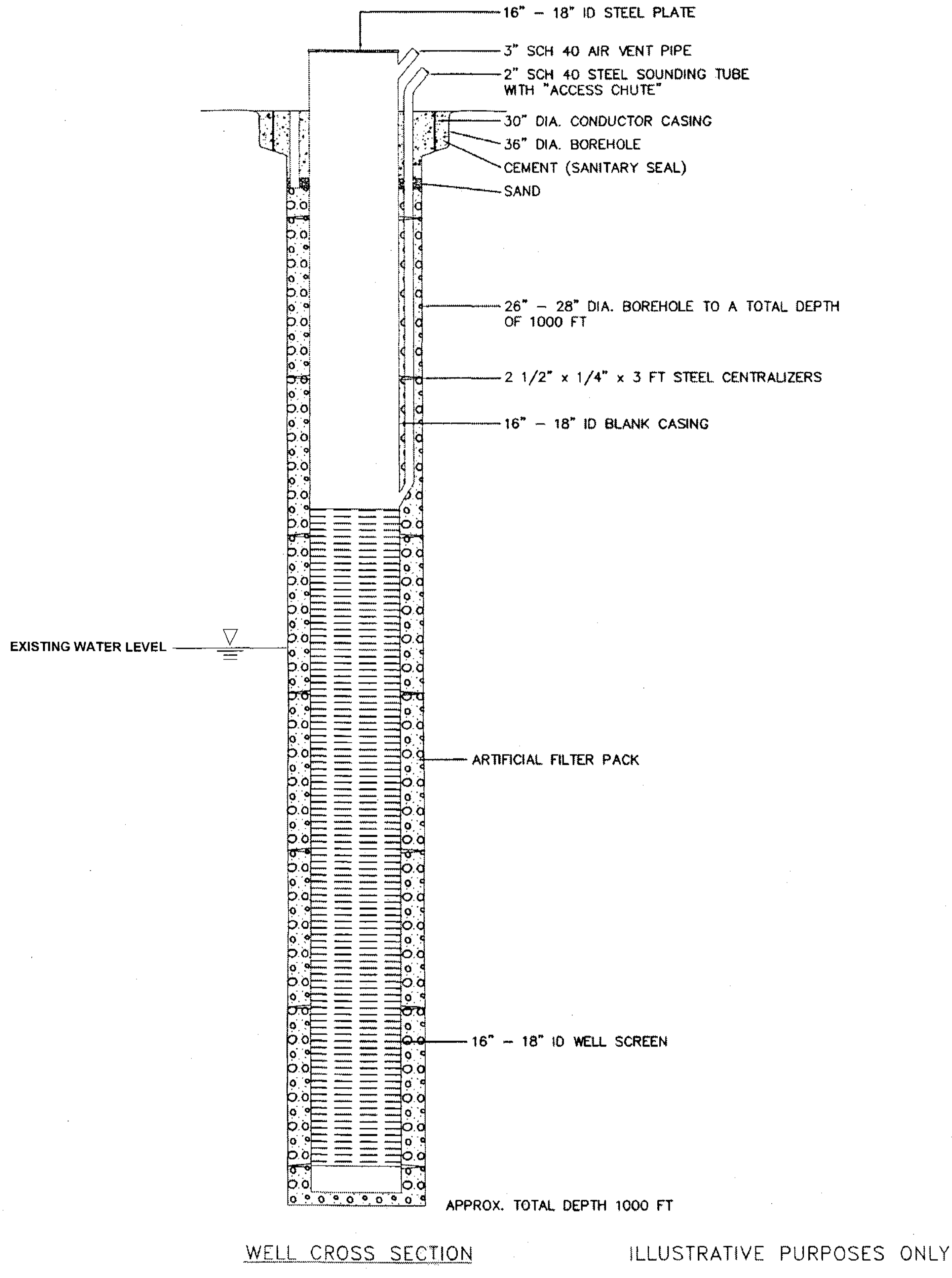

Figure 3-7

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Typical Production Well Cross Section

would be obtained for the project. The surveyed baseline land surface elevations would be compared to each other along with InSAR data collected during the course of the project. The InSAR data would be used to monitor relative changes of land surface elevation, which could be related to aquifer system deformation in the project area. This Pre-Operational InSAR data (collected at two separate times during the year prior to the Operational phase of the project) would complement the land survey data to establish changes in land surface elevations. If recommended by the TRT and the BMG, the InSAR images would be obtained and evaluated semi-annually during the project.

Extensometers (Feature 11)

One extensometer well would be constructed, if recommended by the TRT and the BMG, on the basis of the annual benchmark surveys and evaluation of InSAR images within the area of the highest probability of subsidence (see Figure 3-5). The extensometer would be constructed to measure non-recoverable compaction of fine-grained materials interbedded within the alluvial aquifer systems.

Microgravity Reference Stations (Feature 12)

Up to 10 surveyed reference points would be established for use in conjunction with gravity surveys within the project area (see Figure 3-5) if recommended by the TRT and the BMG. The gravity method (or gravimetry) is a potential field method based on the principle that density differences in subsurface materials (e.g. between unsaturated sediment and saturated sediment) would cause minute, but measurable, changes in the gravity field. Microgravity surveys would be evaluated for estimating changes in the depth to groundwater in areas where wells have not been installed. The microgravity surveys would be calibrated against groundwater levels measured in observation wells. The surveyed reference points would then allow comparison of gravity data at the same location during subsequent surveys. Other surveyed features (i.e. wells, land surface elevation bench marks, etc.) would also be used as reference points for the gravity surveys.

Microgravity surveys, if deemed necessary by the TRT and the BMG, would be conducted annually throughout the term of the Cadiz Project to help assess changes in groundwater levels in areas where no data are available or where access is limited for the installation of observation wells. Reference point locations would be determined from groundwater modeling results during the Pre-Operational phase of the project.

Flowmeter Surveys (Feature 13)

Downhole flowmeter surveys would be generated in five selected extraction wells. The flowmeter surveys would provide data regarding vertical variation in groundwater flow to the well screens. Depth-specific water quality samples would also be collected to assess vertical variation of groundwater quality in the project wellfield area. Data would be used to help refine geohydrologic parameters regarding layer boundaries used in the groundwater models.

Proposed Observation Well Clusters at Bristol Dry Lake (Feature 14)

A total of three new observation well clusters would be installed and monitored in the vicinity of Bristol Dry Lake during the initial phases of the Cadiz Project (see Table 3-1 and Figure 3-4). Two well clusters would be located along the eastern margin of Bristol Dry Lake to monitor the effects of project operations on the movement of the fresh water/saline water interface (see Figure 3-4). One additional well cluster would be installed on the Bristol Dry Lake playa to monitor brine levels and chemistry at different depths beneath the dry lake surface. This well cluster would be positioned in relation to the well clusters at the margin of the dry lake so as to provide optimum data for the density dependent transport model.

Proposed Observation Well Clusters at Cadiz Dry Lake (Feature 15)

Two well clusters would be located along the northern margin of Cadiz Dry Lake to monitor the effects of project operations on the movement of the fresh water/saline water interface in this area (see Figure 3-4). One additional well cluster would be installed on the Cadiz Dry Lake playa to monitor brine levels and chemistry at different depths beneath the dry lake surface.

Evapotranspiration Stations (Feature 16)

Two evapotranspiration (ET) monitoring stations would be established, one each on Bristol and Cadiz dry lakes (see Figure 3-4). Each station would be instrumented to enable the calculation of evapotranspiration using a turbulent flux (eddy correlation) method. Each station would be capable of measuring ambient air temperature, vertical and horizontal wind speed and direction, humidity, water vapor density, solar radiation, net radiation, soil temperature, soil heat flux, and soil water content or soil suction. Each ET station would be equipped with a data logger for data collection and data storage.

Surface Water Monitoring Stations on the Dry Lakes (Feature 17)

A staff gage would be established at the locations of the ET stations on each of the dry lakes. These staff gages would be established to measure surface water accumulation on the dry lakes from storm runoff. A staff gage would consist of a calibrated measuring rod vertically mounted into the lakebed surface. During periods of storm water runoff and surface water accumulation, continuous monitoring of surface water depth would be obtained on each dry lake.

Air Quality Monitoring (Feature 18)

Monitoring at Bristol and Cadiz Dry Lakes

This air quality monitoring feature would evaluate wind-mobilized particulate matter from the dry lake beds. The objective of monitoring would be to detect any increases in the frequency of occurrence of wind-mobilized particulate matter caused by the project, if any. Because these mobilization events are intermittent, continuous monitoring would be employed in order to most accurately integrate dust mobilization and wind data. Open-air nephelometers (instruments that measure the light scattered by particles in the atmosphere), digital cameras, and weather stations would be used.

Monitoring at the Boundary of Clean Air Act Class I Area

A two-stage monitoring approach would be used to address questions regarding the potential for any project-mobilized dust from Bristol or Cadiz dry lakes to contribute to degradation of visibility within Class I areas designated by the Clean Air Act. Stage 1 would have a duration of five years beginning in the Pre-Operational phase of the project and extending into the initial years of the project Operational phase. During this five-year period, two meteorological towers would be installed in the region to provide data on wind speed and direction (see Feature 24).

This baseline wind data would be used in conjunction with lakebed data for wind speed and direction and groundwater levels and soil moisture in a TRT review to determine whether (a) the project could contribute to lakebed dust mobilization and (b) if any project-mobilized lakebed dust could be transported into a Class I area. This review would consider whether existing dust storms on the dry lake beds occur simultaneously with regional winds that are capable of transporting lakebed dust into a Class I area (currently applies to Joshua Tree National Park, but would also apply to Mojave National Preserve if it is designated as a Class I area.). If the review concludes that there is not a potential for project-mobilized dust to reach the Class I area, stage 2 of this analysis would not be implemented. If the potential is determined to exist, then the TRT would recommend implementation of stage 2. The five-year stage 1 monitoring period may be shortened by recommendation of the TRT should it be determined earlier that there is a potential for any project-mobilized dust to be transported to a Class I area.

Stage 2 would require the placement of instrumentation at the boundary of the Class I area capable of measuring changes in visibility and attributing that change to Cadiz Project. It is anticipated that a transmissometer(s) would be utilized to gather visibility data. Baseline visibility data would be gathered prior to any potential project-induced visibility effects and would be compared with visibility data obtained throughout the Operational phase of the project to assess if declines in visibility have occurred. A study design would be developed by the TRT at the time that stage 2 is triggered to identify any other instrumentation and data gathering, including the location and timing of these efforts, necessary to make determinations and recommendations regarding the potential need to modify the operations of the Cadiz Project. The study design would utilize wind and other pertinent data obtained through the Management Plan during stage 1.

In addition to visibility monitoring at the boundaries of Class I areas, any right-of-way granted by BLM may include conditions necessary or appropriate to provide for visibility monitoring in other locations sensitive to adverse impacts on air quality including, but not limited to Mojave National Preserve.

Resistivity Survey (Feature 19)

Resistivity profiles would be conducted at the margins of Bristol and Cadiz dry lakes, if recommended as necessary by the TRT and the BMG, to assess the lateral distribution of brine concentrations in the groundwater in this area. Resistivity is a measure of the specific resistance of a material to the flow of electric current (opposite of electrical conductivity). Groundwater resistivity is based on the ion concentration of the water such that the higher the concentration of ions (salts), the lower the resistivity. This principle may be used to map variation in brine concentrations and lithology at selected locations of the margins of Bristol and Cadiz dry lakes using resistivity profiles.

Results from the resistivity profiles could aid in the location of observation well clusters at the margins of Bristol and Cadiz dry lakes and, if deemed necessary, would be conducted during the Pre-Operational phase of the Cadiz Project.

Gamma-Ray/Dual Induction Downhole Geophysical Logs (Feature 20)

Gamma-ray and dual induction electric logs are planned for the deepest observation wells of each well cluster to be installed at the dry lakes (six total). These downhole geophysical techniques allow for the measurement of groundwater electrical conductivity with depth and could be conducted in observation wells constructed of PVC casing and screen.
Gamma-ray/dual induction geophysical logs are planned as a one-time measurement to be conducted during observation well cluster installation during the Pre-Operational phase of the Cadiz Project.

Weather Stations (Feature 21)

Data from three existing weather stations would be collected over the course of the project (see Figures 3-4 and 3-5). Existing weather stations would include the Mitchell Caverns weather station (located in the Providence Mountains), the project weather station (located in Fenner Gap adjacent to the spreading basins), and the Amboy weather station (located near Bristol Dry Lake in the town of Amboy).

One additional weather station would be established in the higher elevations of the Fenner Watershed (e.g. the Providence or New York Mountains) based on a statistical analysis of regional precipitation patterns from the precipitation stations summarized on Figure 3-8. The statistical analysis would provide a basis for placement of the new weather station in an area that would provide the most meaningful data for further evaluation of available precipitation. Because potential sites for the new weather station are in the Mojave National Preserve, final site selection and installation would be dependent upon approval from the appropriate agency.

The Mitchell Caverns weather station and new stations would provide precipitation, temperature, and other climatic data for the mountain regions of the Fenner Watershed, with the new station providing additional control for the highest elevations of the watershed. The Fenner Gap weather station would provide climatic data in the immediate vicinity of the project area. The Amboy weather station would provide climatic data representative of the lowest area of the regional watershed.

Stream Gage (Feature 22)

Stream flow in the mountainous areas of the Fenner Watershed would initially be monitored using an existing stream gage located in Caruthers Canyon in the New York Mountains near the northerly extent of the watershed (see Figure 3-4). As more data are collected and the surface water and groundwater flow models are expanded and refined, up to two additional gages would be established in areas identified as critical data gaps (see Figure 3-4).

Soil Moisture Sensors (Feature 23)

Soil moisture sensors would be installed to monitor infiltration from natural surface water runoff (as during storm events) if recommended by the TRT and the BMG. Soil moisture sensors would be installed within boreholes drilled at strategic locations near the project area (e.g. Schulyler Wash near Danby). Final location of the infiltration sites, if deemed necessary,

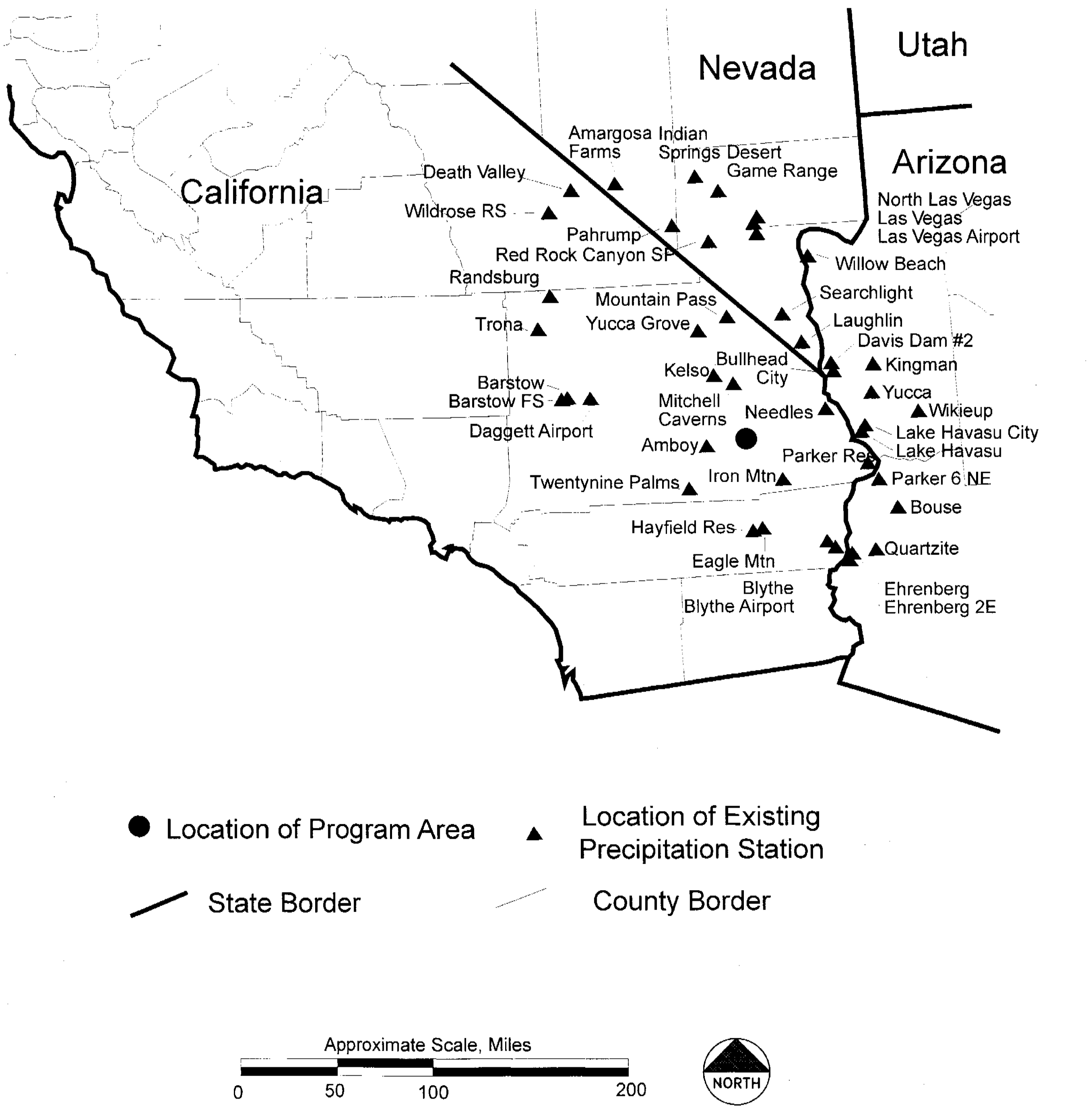

Figure 3-8

Cadiz Groundwater Storage & Dry-Year Supply Program

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Location of Precipitation Stations in the Desert Southwest Region would be based on evaluation of aerial photographs, analysis of available storm runoff records in the upper Fenner Watershed, preliminary analysis of storm runoff routing from the revised rainfall runoff model, field reconnaissance, and permission for physical access to the monitoring sites.

Soil moisture sensors would be installed in the unsaturated zone to measure surface water infiltration below the root zone of plants. Soil cores would be collected at selected intervals during drilling and logged according to the USCS standards. Selected soil samples would be analyzed for physical parameters of relative permeability, water characteristic curves, porosity, and bulk density. Other samples would be analyzed for moisture content, water potential, chloride, and tritium.

Meteorological Towers (Feature 24)

In addition to the four weather stations (Feature 21), two 10-meter-tall meteorological towers with wind instrumentation would be installed in the region to collect data on wind direction and speed. Instruments on each tower would include an anemometer, wind vane, and data acquisition system. The meteorological towers would be located in the region to determine whether dust emissions from Bristol and Cadiz dry lake beds could be blown into a Clean Air Act Class I area (currently applies to Joshua Tree National Park). Conceptual locations for the towers are (1) in the vicinity of Orange Blossom Wash, and (2) in the unnamed valley between the Sheephole and Calumet Mountains and between Bristol Dry Lake and the northern boundary of Joshua Tree National Park (see Figure 3-3). These locations would be refined or revised, as appropriate, by recommendation of the TRT and the BMG. The meteorological towers would be installed in the Pre-Operational phase of the Cadiz Project and would operate for a period of five years. The TRT may recommend that this period be shortened, should it be determined earlier that there is a potential for any project-mobilized dust to be transported to a Class I area.

For an implementation schedule of these 24 monitoring features, see Figure 3-9.

3.6 MONITORING, TESTING AND REPORTING PROCEDURES

General and specific monitoring features, which are described in the context of Critical Resources in Tables 3-1 and 3-2, would be monitored at varying frequencies during three project periods: Pre-Operational, Operational, and Post-Operational. The adequacy/necessity of the monitoring network and frequency would be reevaluated by the TRT as necessary (see Figure 3-10), and recommendations made to the BMG.

3.6.1 MONITORING OF SPRINGS ON MOJAVE NATIONAL PRESERVE AND BLM-MANAGED LANDS IN THE AFFECTED WATERSHEDS

3.6.1.1 Pre-Operational Monitoring of Springs

During the Pre-Operational phase of the monitoring period, 28 springs would be characterized and approximately eight springs would be selected for ongoing monitoring during the term of the Cadiz Project. In addition, the S-Series wells would be installed and monitored.

Metropolitan Water District of Southern California / Cadiz, Inc.
Cadiz Groundwater Storage and Dry-Year Supply Program

Management Schedule for Proposed Monitoring Activities

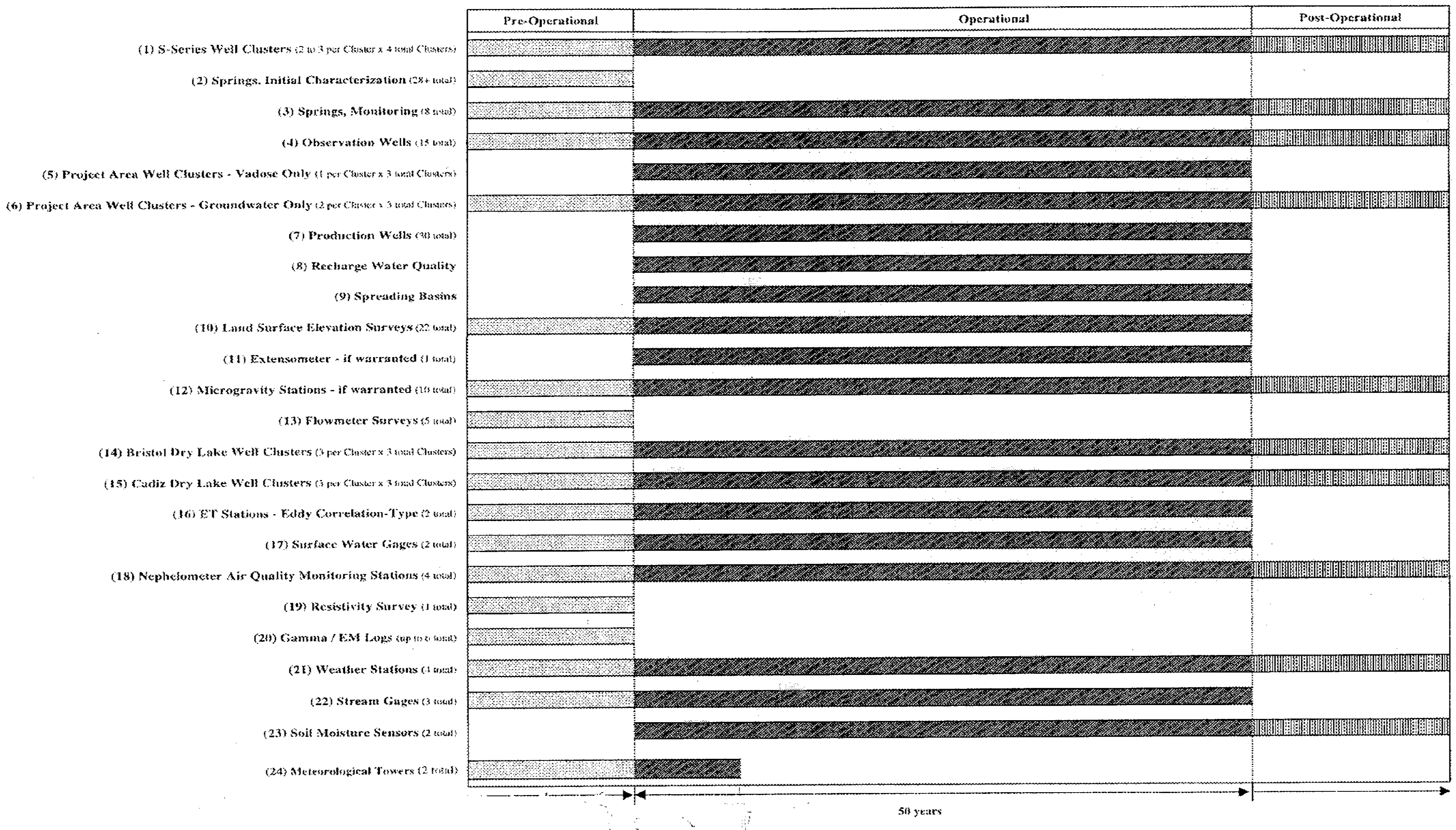

Figure 3-9

Cadiz Groundwater Storage & Dry-Year Supply Program

Supplement to the Draft EIR/EIS

Management Schedule for Proposed Monitoring Activities

Groundwater Levels in the S-Series Wells (Feature 1)

During the Pre-Operational phase, groundwater levels would be monitored in the S-Series observation wells on a continuous basis using downhole electronic pressure transducers, compensated for atmospheric pressure. Pressure transducers would be installed below the water table within the wells and record relative differences in head pressure above the transducer setting on a regular basis. Head pressures would be converted to water level data and stored in data loggers at each well site.

Springs (Features 2 and 3)

During the Pre-Operational phase, field reconnaissance would be conducted of 28 known springs in the Fenner and Orange Blossom Wash watersheds. Each of these springs would be classified based on discharge rate in accordance with the following criteria as specified by Meinzer (1942).

Data to be collected and recorded at each spring would include:

- GPS coordinates
- Spring Type
- Geology of Immediate Surroundings
- Vegetation Type and Cover
- Flow Rate and/or Water Level in Associated Shallow Piezometer
- Temperature, Electrical Conductivity, and pH

All data would be recorded on standardized field data collection forms. Photographs of each spring would be taken to document Pre-Operational physical conditions.

- Based on the initial field reconnaissance, approximately eight springs would be identified for monitoring.

- Two springs would be monitored continuously during the Pre-Operational and Operational phases of the Cadiz Project using small diameter (3/4- to 1-inch diameter) PVC piezometers installed in the immediate vicinity of the selected springs. The piezometers would be hand-driven to a point of refusal or a depth of 10 feet below the water table. Each piezometer casing would be screened from the total depth to the ground surface. The piezometers would be equipped with downhole pressure transducers for measuring relative changes in hydraulic head near the spring.

- The remaining springs would be monitored semi-annually during the rest of the Pre-Operational phase, and throughout the term of the project. The TRT would reevaluate the adequacy of the monitoring frequency as needed.

- During the Pre-Operational monitoring, water quality samples from the approximately eight selected springs on a semi-annual basis would be collected and analyzed for general mineral and physical parameters, tritium/He^3, chlorofluorocarbons, deuterium, and stable isotopes of hydrogen and oxygen to help determine the age and source of water from the springs (see Table D-2 in Appendix D for specific constituents). All samples would be collected in laboratory prepared containers and submitted to a State-certified analytical laboratory or other qualified laboratory for analysis according to the protocols described in Appendices C and D.

3.6.1.2 Operational Monitoring of Springs

During the Operational phase, groundwater levels would be monitored in the S-Series observation wells on a continuous basis using downhole electronic pressure transducers, compensated for atmospheric pressure.

Spring flow and spring water parameters (temperature, electrical conductivity, and pH) in six of the approximately eight springs selected would be monitored in the field on a semi-annual basis throughout the term of the Cadiz Project. Water levels measured in piezometers in the immediate vicinity of two of the approximately eight springs would be monitored continuously using downhole pressure transducers. Spring monitoring frequency would be reevaluated by the TRT as necessary.

3.6.1.3 Post-Operational Monitoring of Springs

During the Post-Operational phase, groundwater levels would be monitored in the S-Series observation wells on a continuous basis using downhole electronic pressure transducers, compensated for atmospheric pressure.

Spring flow and spring water parameters (temperature, electrical conductivity, and pH) in six of the approximately eight springs selected, would be monitored in the field on a semi-annual basis during the Post-Operational monitoring period until it is no longer recommended as necessary by the TRT and the BMG. Spring monitoring frequency would be reevaluated by the TRT as necessary.

3.6.2 AQUIFER SYSTEM

3.6.2.1 Pre-Operational Monitoring Aquifer System

Groundwater Levels

During the Pre-Operational monitoring period, static groundwater levels would be monitored on a monthly basis in each of the observation wells identified as Feature 4 in Tables 3-1 and 3-2. Monthly groundwater level monitoring would begin upon project approval by Metropolitan and the BLM. Groundwater levels would be measured in accordance with the monitoring procedure presented in Appendix B.

Groundwater levels in the cluster wells that were screened below the static water table would be monitored continuously during the Pre-Operational phase of the Cadiz Project using downhole pressure transducers. Monitoring would begin immediately upon completion of installation and development of the cluster wells.

TABLE 3-3
SPRING CLASSIFICATION CRITERIA

Magnitude	Discharge
First	100 cubic feet per second (cfs) or more
Second	10 to 100 cfs
Third	1 to 10 cfs
Fourth	100 gallons per minute (gpm) to 1 cfs
Fifth	10 to 100 gpm
Sixth	1 to 10 gpm
Seventh	1 pint per minute to 1 gpm
Eighth	Less than 1 pint per minute

The initial project monitoring well network would be supplemented, as recommended as necessary by the TRT and the BMG, with a network of microgravity stations located in the immediate project vicinity (Feature 12). The microgravity stations are intended to measure changes in the depth to groundwater by identifying subsurface density differences. Such microgravity data would be used, in conjunction with water levels measured in observation wells.

Groundwater Quality

Groundwater samples would be collected on a quarterly basis from five of the 15 wells specified as Feature 4 in Tables 3-1 and 3-2 during the Pre-Operational phase of the Cadiz Project. Groundwater samples would be collected on a quarterly basis from wells within each project area well cluster that are screened below the static groundwater level (Feature 6). It is important that samples collected to test for groundwater quality are representative of the aquifer groundwater. This implies that the wells are properly developed in order that the sampling obtains representative samples of aquifer groundwater quality. If this cannot be achieved, then alternative sampling would be recommended by the TRT and may include production wells already equipped with deep well pumps.

Groundwater samples would be collected from the remaining 10 observation wells on an annual basis. All samples would be collected according to the protocol described in Appendix C. Field parameters such as groundwater temperature, pH, electrical conductivity, and total dissolved solids (TDS) would be collected at each well during well purging and prior to sampling. Samples from each well would be analyzed for the general mineral and physical parameters specified in Appendix D. In addition, all samples collected during the Pre-Operational phase would also be analyzed for bromide, boron, iodide barium, arsenic, nitrate, and perchlorate. The sample analytical protocol is presented in Appendix D.

Subsidence

All benchmarks would be established and surveyed on an annual basis by a California licensed land surveyor. Horizontal and vertical accuracy would be established in accordance with a second order Class I survey standard (1:50,000). InSAR satellite data would be obtained during two different seasons during the Pre-Operational monitoring period and evaluated for use to supplement the land survey data if recommended by the TRT and the BMG.

Downhole Flowmeter (Spinner), Water Quality and Temperature Surveys

Downhole flowmeter surveys would be conducted in five selected extraction wells. Depth-specific water quality samples would also be collected at the time of the flowmeter surveys. Samples collected for water quality would be analyzed for general mineral and physical parameters: chloride, bromide, boron, iodide, barium, stable isotopes of oxygen and deuterium, tritium and isotopes of carbon. Vertical temperature surveys would be conducted on two of the existing extraction wells, at each cluster well location along the margins of the dry lakes,[5] and one upgradient observation well. The temperature surveys, in conjunction with field-measured temperature readings on observation wells, would be used to generate a depth-specific isotherm map of the project area.

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[5] At each cluster well location the deepest well would be surveyed.

3.6.2.2 Operational Monitoring of Aquifer System

Groundwater Level Monitoring Procedures

Groundwater levels would be monitored on an annual basis and on a monthly basis for the first three months after start-up and shut-down of each recharge and extraction cycle in each of the observation wells identified as Feature 4 in Tables 3-1 and 3-2. In addition, continuous monitoring would be implemented on Well T6N/R15E-29Q1, shown on Figure 3-5, and another well to be recommended by the TRT. Groundwater levels would be measured in accordance with the monitoring procedure presented in Appendix B.

Microgravity surveys may be conducted on an annual basis during the Operational phase to compare groundwater levels with previous surveys if recommended by the TRT and the BMG.

Groundwater Quality Monitoring Procedures

During the Operational phase, groundwater samples would be collected on an annual basis from the observation wells specified in Table 3-2. All samples would be collected according to the groundwater sampling and analytical protocols specified for the Operational phase of the Cadiz Project in Appendices C and D. Results of water quality analyses would be summarized in tables in the annual report. Measurement of vertical temperature profiles may also be recommended by the TRT on a periodic basis in selected wells.

Groundwater Production Monitoring

Data from the wellfield (project wells and Cadiz agricultural wells) would be collected to provide information on the groundwater levels and discharge rates. Production data from the project wells would be verified using totaled readings of flow at the Iron Mountain Pumping Plant.

Recharge Water Quality (Inflow to Spreading Basins)

During storage operations, deliveries of Colorado River water to the project spreading basins would be sampled at Lake Havasu. Water quality samples would be collected and analyzed on a weekly basis by Metropolitan. Annually collected samples of Colorado River water would be analyzed for a full suite of Title 22 analyses (see Appendix D).

Spreading Basins

All spreading activities would be monitored with periodic site visits for inspection and maintenance. Notes regarding spreading basin berm conditions, berm leakage, siltation, algae growth, and other observations would be recorded. Spreading basins would be inspected monthly during storage cycles of the Cadiz Project. During recharge operations the depth of surface water in the spreading basins would be measured on a regular basis using graduated staff gages located within each respective subbasin.

Subsidence Monitoring

A State of California licensed land surveyor would annually survey the benchmark network. Results would be included, along with any available InSAR satellite results and comparisons, in the annual report.

3.6.2.3 Post-Operational Monitoring of Aquifer System

During the Post-Operational phase of the Cadiz Project, groundwater levels would be monitored on a continuous basis in the project well clusters screened beneath the static groundwater level (Feature 6) until no longer recommended as necessary by the TRT and the BMG, and annually in the 15 observation wells (Feature 4) located in the project area. Groundwater level monitoring frequency would be reevaluated by the TRT as necessary. If necessary, microgravity surveys would also be conducted on an annual basis or such period, as recommended by the TRT and the BMG, during the Post-Operational monitoring period to supplement the observation well data. Water quality samples would be collected on an annual basis during the Post-Operational phase.

3.6.3 BRISTOL AND CADIZ DRY LAKES

3.6.3.1 Pre-Operational Monitoring of Bristol and Cadiz Dry Lakes

Groundwater Levels

During the Pre-Operational phase, static groundwater levels would be monitored on a continuous basis from each well cluster (Features 14 and 15) using downhole pressure transducers. Monitoring would begin immediately following well installation and development.

Data would be obtained documenting the initial depth to groundwater and soil moisture within this continuous soil column between the groundwater level and the lakebed surfaces during installation of well clusters at Bristol and Cadiz dry lake margins and on the dry lakes (Features 14 and 15).

Groundwater Quality

Groundwater samples would be collected on a quarterly basis from the dry lake well clusters (Features 14 and 15) after well installation but prior to startup of the Cadiz Project. All samples would be collected according to the protocol described in Appendix C. Field parameters such as groundwater temperature, pH, electrical conductivity, and total dissolved solids would be collected at each well during well purging and prior to sampling. Samples from each well would be analyzed for the general mineral and physical parameters specified in Appendix D. Samples from selected wells would also be analyzed for bromide, arsenic, nitrate, and perchlorate. The sample analytical protocol is presented in Appendix D.

Geophysical Surveys

A resistivity survey would be conducted along the margins of Bristol and Cadiz dry lakes to aid in the location of well clusters in this area.

Gamma ray and dual induction electric logs are planned for the deepest observation wells of each well cluster to be installed at the dry lakes (up to six total). Downhole geophysical logging would be conducted after the deep wells were installed.

3.6.3.2 Operational Monitoring of Bristol and Cadiz Dry Lakes

Groundwater Levels

During the Operational phase, static groundwater levels would be monitored on a continuous basis from each well cluster

(Features 14 and 15) using downhole pressure transducers.

Groundwater Quality

Groundwater samples would be collected on a semi-annual basis from the dry lake well clusters (Features 14 and 15) over the term of the Cadiz Project. All samples would be collected according to the protocol described in Appendix C. Field parameters such as groundwater temperature, pH, electrical conductivity, and total dissolved solids would be collected at each well during well purging and prior to sampling. Samples from each well would be analyzed for the general mineral and physical parameters specified in Appendix D. The sample analytical protocol is presented in Appendix D.

Evapotranspiration

Evapotranspiration monitoring stations, located on Bristol and Cadiz dry lakes, would record ambient air temperature, vertical and horizontal wind speed and direction, humidity, water vapor density, solar radiation, net radiation, soil temperature, soil heat flux and soil water content or soil suction on an hourly basis.

Surface Water

During periods of flooding, measurements of surface water depth data would be obtained from automated instrumentation backed up by manual readings of the staff gages on each dry lake, as needed.

3.6.3.3 Post-Operational Monitoring of Bristol and Cadiz Dry Lakes

Groundwater Levels

During the Post-Operational phase, static groundwater levels would continue to be monitored on a continuous basis from each well cluster (Features 14 and 15) using downhole pressure transducers. The necessity of continuing groundwater level monitoring would be reevaluated by the TRT as necessary.

Groundwater Quality

Groundwater samples would be collected on an annual basis from the dry lake well clusters (Features 14 and 15) during the Post-Operational phase of the Cadiz Project. All samples would be collected according to the protocol described in Appendix C. The necessity of continuing groundwater quality monitoring would be reevaluated by the TRT as necessary.

3.6.4 AIR QUALITY

3.6.4.1 Pre-Operational Air Quality and Related Monitoring

During the Pre-Operational phase, air quality monitoring would consist of gathering baseline data with respect to groundwater between the project area and the dry lake beds, at the lake bed margins and on the dry lake beds, surface soil moisture at the dry lake beds, and ET, air temperature and wind velocity on the dry lake beds. Open-air nephelometers would be installed at the dry lake beds to collect data on ambient dust mobilization from the dry lake beds. Additionally, data would be collected with the installation of the well clusters on the lake bed margins and within the dry lake beds establishing initial depth to groundwater and a soil moisture profile between the groundwater and surface of the dry lake beds. In the case that the Pre-Operational baseline data (monitoring, modeling, and/or statistical analyses) alters understanding of the relationship between groundwater resources and air quality, the TRT may recommend refinement of the groundwater level Action Criteria for air quality to the BMG.

Additionally, two 10-meter-tall meteorological towers with wind instrumentation would be installed in the region to collect data on wind speed and direction. Instruments on each tower would include an anemometer, wind vane, and data acquisition system. Conceptual locations for the towers are (1) in the vicinity of Orange Blossom Wash north of Bristol Dry Lake, and (2) in the unnamed valley between the Sheephole and Calumet Mountains and between Bristol Dry Lake and the northern boundary of Joshua Tree National Park (see Figure 3-3). These locations would be refined or revised, as appropriate, and would operate for a period of up to five years, or for a period determined necessary as recommended by the TRT and the BMG.

The purpose of the air quality monitoring would be to anticipate, avoid, and confirm avoidance of the potential effects, if any, of project operations on air quality due to the mobilization of wind-blown dust on Bristol or Cadiz Dry Lake. Information would be collected from a broad spectrum of monitoring features as described here.

Well Clusters

Well clusters would provide information regarding the natural moisture content of the soil above the groundwater surface as well as groundwater level information for different depth-specific zones beneath the dry lakes. Groundwater levels in the wells would be monitored as described in Section 3.6.3.

Evapotranspiration Stations

Evapotranspiration monitoring stations, located on Bristol and Cadiz dry lakes, would record ambient air temperature, vertical and horizontal wind speed and direction, humidity, water vapor density, solar radiation, net radiation, soil temperature, soil heat flux and soil water content or soil suction on an hourly basis.

Evapotranspiration stations would be installed in the immediate vicinity of the well clusters on the dry lakes (see Section 3.5.3.3). The evapotranspiration stations would be equipped with instrumentation to monitor soil water content and soil suction on an hourly basis throughout the term of the project. Soil moisture data collected from the evapotranspiration stations during the pre-operational phase of the project, in conjunction with soil moisture analyses from continuous core samples collected during drilling, would provide a baseline soil moisture condition with which to compare data collected during the operational phase of the project. Soil moisture data would be evaluated in the context of measured groundwater levels to establish a relationship between changes in groundwater levels, soil moisture content, and potential for dust mobilization.

Surface Water Staff Gages

During periods of flooding, continuous monitoring of surface water depth would be obtained on each dry lake. Staff gages would be established at each evapotranspiration station to measure surface water accumulation on the dry lakes as a result of storm runoff (see Feature 17).

Surface water effects on soil moisture and shallow groundwater levels would be evaluated to distinguish natural conditions from those attributable to project operations.

Open-Air Nephelometers

This air quality monitoring feature would detect wind-mobilized particulate matter from the dry lake beds with the objective of detecting any increases in this wind-mobilized particulate matter due to project operations. Because this particulate matter is mobilized by wind storms and is intermittent, continuous monitoring would be employed using open-air nephelometers, which measure the light scattered by particles in the atmosphere. This monitoring would allow comparison of wind velocity data to short-term increases in dust mobilization.

Weather Stations and Analysis of Meteorological Data

Meteorological data collected as part of the groundwater monitoring program, would be evaluated to identify the wind speeds that lead to high emissions of wind-mobilized particulate matter. A variety of statistical analyses would be used, including both parametric and non-parametric techniques, such as cluster analysis, analysis of variance, etc. The analyses would also include factors that could affect surface characteristics, such as precipitation, storm flow run-on and surface moisture. These analyses would be performed separately for data collected during Pre-Operation and Operational monitoring to attempt to detect any statistically significant reductions in threshold wind speed. If statistically significant differences are identified, additional data, such as ground water levels at the edges of the lakes, would be evaluated to help determine if the differences could have been caused by the project's operations.

3.6.4.2 Operational Air Quality Monitoring

All air quality monitoring activities would continue on an on-going basis, unless otherwise determined. As appropriate, revisions to the air quality Action Criteria may be recommended by the TRT to the BMG should monitoring, modeling, and/or statistical analyses so indicate. The BMG would recommend revisions to the Action Criteria as appropriate (Section 3.9.2).

3.6.4.3 Post-Operational Air Quality Monitoring Stations

During the Post-Operational phase of the project, the nephelometers would continue to monitor airborne particulate matter on Bristol and Cadiz dry lakes. This information would be correlated with groundwater levels, wind velocities, and lake bed soil moisture. The necessity of continuing the air quality monitoring would be tied to the TRT and BMG review of groundwater level monitoring.

Weather Stations

During the Post-Operational phase of the project, wind direction and velocity and ET would continue to be monitored on Bristol and Cadiz dry lakes. This information would be correlated with nephelometer readings, groundwater levels, and lakebed soil moisture. The necessity of continuing the weather station monitoring would be tied to the TRT and BMG review of groundwater level monitoring.

Soil Moisture Sensors

During the Post-Operational phase of the project, soil moisture would continue to be monitored on Bristol and Cadiz dry lakes. This information would be correlated with nephelometer readings, groundwater levels, and wind velocities. The necessity of continuing the weather station monitoring would be tied to the TRT and BMG review of groundwater level monitoring.

3.6.5 OTHER MONITORING (REGIONAL)

3.6.5.1 Pre-Operational Regional Monitoring

Climatological Monitoring

Meteorological monitoring would be undertaken during the Pre-Operational phase of the project utilizing the four weather stations. Data to be collected at the Mitchell Caverns and Amboy stations would include ambient air temperature, evaporation, and precipitation (including snow accumulation). Data to be collected at the Fenner Gap and a new weather station would include ambient air temperature, evaporation, precipitation, wind speed and direction, barometric pressure, relative humidity, and soil temperature. In addition, each weather station would be equipped with precipitation collectors to be used for chemical analyses. Data from the Mitchell Caverns and Amboy stations would be obtained in electronic form on a yearly basis from the San Bernardino County Flood Control District. Data from the Fenner Gap and new weather stations would be continuously recorded.

The project weather station would include a fresh water evaporation pan that is set up in accordance with National Weather Bureau standards. Water levels within this pan would be generally maintained between four and eight inches. Pan water levels would be measured using three internal gages located 120 degrees from each other. The pan water level would be measured on a monthly basis as the average of the three gages.

Surface Water Flow

An existing stream gage located in Caruthers Canyon in the New York Mountains would be utilized to monitor stream flow in the higher elevations of the watershed. The gage site would be inspected in the field to assess:

- Hydraulic Control (in an area where the stage discharge relationship is constant and measurable);
- Channel Geometry (well established single flowing channel that is relatively straight and doesn't meander); and
- Local Tributary Inflow.

If warranted, two additional stream gage locations would be identified as a result of additional rainfall/runoff modeling. Each new gage would be constructed and monitored in accordance with Rantz et al., 1982 (Appendix B) and the United States Geological Survey's *Surface Water Quality Assurance Plan for the California District of the United States Geological Survey* (Meyer, 1996).

Infiltration Monitoring

Subsurface soil moisture sensors installed in boreholes strategically located in major washes and nearby terraces would record soil moisture on a daily basis unless otherwise recommended by the TRT and the BMG. If feasible, the soil moisture sensor boreholes would be positioned to correspond to stream gage locations so surface water runoff/infiltration relationships in the sandy-bottomed washes could be quantified.

3.6.5.2 Operational Regional Monitoring

Climatological Monitoring

Climatological data would be collected throughout the term of the Cadiz Project using the weather stations and procedures described in Section 3.6.4. Meteorological towers to collect wind data would continue to operate in the early years of the Operational phase, and would conclude after up to five years of data collection.

Stream Gage Monitoring

Surface water flow at the Caruthers Canyon stream gage would be downloaded periodically from the United States Geological Survey website. Surface water flow at this gage is recorded on a continuous basis. Surface water data would be tabulated and summarized in the annual reports. Stream flow data from any newly installed gages would also be recorded on a daily basis.

Infiltration Monitoring

During the project, subsurface soil moisture beneath the washes selected during the Pre-Operational phase would be monitored as described in section 3.6.4.1.

3.6.6 QUALITY ASSURANCE/ QUALITY CONTROL

For this project, quality assurance (QA) is defined as the integrated approach designed to assure reliability of monitoring and measurement data. Quality control (QC) is defined as the routine application of specified procedures to obtain prescribed standards of performance in the monitoring and measurement process (ASTM D-18). Metropolitan would be responsible for assuring that the precision, accuracy, and completeness of data collected during the project were known and documented.

All groundwater samples collected during the Pre-Operational and Operational phases would be placed in laboratory-prepared sample containers and properly labeled, packaged and preserved, prior to submittal to the laboratory. All groundwater samples would be submitted to the laboratory under chain-of-custody protocol within 24 to 48 hours of collection.

All analytical work would be conducted by a State of California certified analytical laboratory. Laboratory calibration procedures would be conducted in accordance with approved Environmental Protection Agency (EPA) guidelines and the recommendations promulgated in 21 CFR Part 58 "Good Laboratory Practices" (see Appendix D). All groundwater samples would be analyzed in accordance with standard EPA or ASTM methods.

QA/QC reports from the laboratory would be provided with the analytical reports and included with the annual reports. All data would be validated with respect to accuracy, precision, and completeness to ensure that they are representative of actual field conditions.

Use of the nephelometers would follow protocols to be developed that would include procedures for routine operational checks, calibrations and data validation. The instrumentation on the meteorological towers would be calibrated using guidelines set forth in the EPA *Quality Assurance*

Handbook for Air Pollution Measurement Systems, Vol. IV: Meteorological Measurements, March 1995.

3.6.7 DATA MANAGEMENT

During the course of the Cadiz Project, a large amount of data would be collected, stored, processed, analyzed, tabulated, and presented in annual reports. Detailed procedures for the management of the project database are presented in Appendix E.

3.6.8 REPORTING PROCEDURES

Annual reports summarizing all monitoring data would be prepared as described below. The annual report would include a refinement of the basin parameters, monitoring data, and input and output from refined groundwater models. The TRT and BMG would have other reports prepared as necessary, such as a baseline conditions report or Pre-Operational report.

3.6.8.1 Annual Reports

Baseline groundwater level and groundwater quality conditions would be established for comparison with the data compiled for each annual report. Historical records, pre-dating Cadiz Project operations, would be used to establish baseline conditions whenever feasible. The results of the first land survey and any initial InSAR data obtained would serve as the baseline condition for annual comparison.

The Pre-Operational phase and initial years of the Operational phase would be used to collect baseline air quality dust mobilization data on Bristol and Cadiz dry lakes, and to collect regional data on wind speed and direction. The visibility data from the dry lake beds would be used to establish a baseline for future evaluations of project effects. The regional wind data would be used to determine if any project mobilized dust could be transported into a Class I area designated by the Clean Air Act (currently applies to Joshua Tree National Park).

Metropolitan would be responsible for preparation of the annual reports beginning one year after commencement of project construction, which would contain the following components:

- Baseline water level and water quality conditions (to be defined in the first annual report). Presentation of baseline conditions would include water level elevation contours, water quality contours, and a figure showing the results of the initial land survey;
- Tables summarizing groundwater production for each project extraction well;
- Tables summarizing depth to static water level and groundwater elevation measurements for all observation wells;
- Inventory of springs;
- Hydrographs for all observation wells;
- Groundwater elevation contours;
- Tables summarizing water quality analyses for the observation wells;
- Results of land subsidence monitoring surveys and any changes relative to baseline;
- Summary tables of any data collected from wells owned by neighboring landowners in proximity to the project

area (provided that permission was granted for such data collection);

- Summary of project developments, such as changes in storage or extraction operations or construction of new production wells;
- Discussion of project storage and extraction operations, and trends in groundwater levels and groundwater quality as compared to the baseline conditions;
- Updated groundwater flow and quality model results;
- Tables summarizing changes in frequency or severity of dust mobilization recorded on Bristol and Cadiz dry lakes and analysis correlating dust emissions with wind speed, groundwater levels underlying the dry lake beds, and soil moisture on the lake bed surfaces;
- Tables and figures (wind roses) summarizing wind data from regional meteorological towers addressing wind speed and direction, and stability frequency distributions. This data would be collected for up to five years.
- Summary of TRT meetings and recommendations.

All annual reports would include electronic data files and model input and output files. The annual reports would be available to agencies, organizations, interest groups and the general public upon request from Metropolitan. The annual reports would be distributed to the lead and cooperating federal agencies, San Bernardino County, and made available to the public electronically.

3.6.8.2 Five-Year Report

Metropolitan would prepare a five-year report five years from commencement of construction, which would contain the following components in addition to the components of previous annual reports:

- Summary of total project storage and extraction operations;
- Documentation of any trends in groundwater levels evident from the monitoring data;
- Documentation of any trends in water quality measurements evident from the monitoring data;
- Contours of the most recent static groundwater level elevations and groundwater level elevation changes over the previous five years;
- Documentation of any impacts to wells owned by neighboring landowners (provided that permission was granted to monitor such wells); and
- Summary of regional wind data (in first five-year report only) with conclusions for potential for project-mobilized lakebed dust to be transported into a Class I area designated by the Clean Air Act (currently applies to Joshua Tree National Park).

As part of the evaluation of the hydrogeology of the project area, the five-year report would also include:

- Hydrogeologic analysis and interpretation of all project storage and extraction operations during the five-year period;

- Hydrogeologic analysis and interpretation of all water level elevation, water quality, and land survey data collected during the five-year period;

- Results of refined model output from the rainfall-runoff model, unsaturated and saturated groundwater flow and solute transport models, the density dependent groundwater flow model and the solute transport model;

- Detailed evaluation of impacts (if any) of project operations on surface or groundwater resources;

- Recommended modifications to the Management Plan to address any identified inadequacies; and

- Recommended actions to prevent declines in Pre-Operational static groundwater levels in excess of 100 feet at the end of project operations or lead to projections of a water level decline exceeding any action level criteria.

All five-year reports would include electronic data files and model input and output files. The annual reports would available to agencies, organizations, interest groups and the general public upon request from Metropolitan. The five-year report would be distributed to the lead and cooperating federal agencies, San Bernardino County, and made available to the public electronically.

3.7 ACTION CRITERIA, DECISION-MAKING PROCESS AND CORRECTIVE MEASURES

This Management Plan identifies specific quantitative criteria that would "trigger" TRT review to determine whether an impact is attributable to the project operations[6], and if so, which specific corrective measures would be implemented to avoid adverse impacts to Critical Resources. It is the intent of this Management Plan to identify deviations from natural conditions at monitoring features as early as possible in order to identify and prevent the occurrence of adverse impacts to Critical Resources as a result of project operations. Critical Resources, Action Criteria, the decision-making process, and potential corrective measures are discussed below and summarized in Table 3-4.

The initial Action Criteria and corrective measures presented in this Management Plan are considered conservative and may be refined throughout the term of the Cadiz Project. The TRT would have the discretion to recommend such refinements to the BMG, and any such refinement would occur in accordance with the terms of this Management Plan. Regardless of any action of the BMG, BLM would retain control over compliance with the Management Plan through terms and conditions of the right-of-way grant(s). These Action Criteria are intended to be used as predictors of potential impacts to Critical Resources, and exceedance of the trigger levels does not necessarily constitute an impact to Critical Resources.

[6] 'Attributable to project operations' as used in this document includes both the Cadiz Project and Cadiz Valley Agricultural Development.

TABLE 3-4
SUMMARY OF ACTION CRITERIA, IMPACTS AND CORRECTIVE MEASURES (CONTINUED)

Potential Impact	Method of Measurement	Triggers (Action Criteria)	"Close Watch" Measures	Corrective Measures
Adverse Impacts to Springs	Groundwater Observation Wells (S-Series Wells)	Measured Water Level Change in Excess of 1 ft in Any S-Series Observation Wells	TRT to Determine if Groundwater Level Changes Were Above Background Levels and Directly Attributable to Project Operations.	Modification of Project Extraction Operations to Prevent Adverse Impacts.
Adverse Impacts to Indigenous Groundwater Quality from Spreading Colorado River Water	CRW Sample Collection/Analysis at Lake Havasu	TDS Concentrations in CRW Exceeding 1,000 mg/L Using a Four Week Moving Average	Verification Monitoring (One Round)	Curtail Putting CRW into Storage, or Provide Treatment Before Recharging.
Adverse Impacts to Wells Owned by Neighboring Land Owners	Groundwater Observation Wells	Written Complain Stating Adverse Impacts to Yields and/or Increased Pumping Costs and/or Degraded Water Quality in Wells Owned by Neighboring Land Owners	Provision of Supplemental Water to Impacted Party Investigation to Determine if Caused by Project Operations, and Significance of Impact	Deepen Well / Improve Well Efficiency. Blend Impacted Well Water with Another Local Source Modify Project Storage and Withdrawal Operations. Construct Replacement Wells.
Land Subsidence	Benchmark Stations; InSAR; Extensometers (if warranted)	Elevation Changes of Greater than 0.5 ft within the Project Area Non-Recoverable Compaction Equals or Exceeds 0.5 ft	TRT to Determine if Elevation Changes were Directly Attributable to Project Operations Construction of Extensometer	Repair Damaged Structures. Modification of Program Wellfield Operations to Halt Aquifer Compaction.
Liquefaction	Groundwater Observation Wells	Static Groundwater Levels Measure Less than 50 ft Below Ground Surface Outside a Radius of 500 ft from the Boundary of the Project Spreading Basins	Verification Monitoring	Modify Project Operations to Lower Groundwater Levels Such That Minimum Depth to Static Groundwater is Greater Than 50 ft.
Hydrocompaction	Benchmark Stations	Tangible Damage (3 ft Drop in Elevation) in the Project Spreading Basin Area	None	Repair or Replace Damaged Structures

TABLE 3-4
SUMMARY OF ACTION CRITERIA, IMPACTS AND CORRECTIVE MEASURES (CONTINUED)

	Method of Measurement	Triggers (Action Criteria)	"Close Watch" Measures	Corrective Measures
Induced Flow of Lower-Quality Water from Bristol and Cadiz Dry Lakes	Groundwater Observation Wells (Cluster Wells at Dry Lakes)	TDS Concentration Changes in Excess of 25% of Background Concentrations in Cluster Wells at the Margin of the Dry Lakes	TRT to Determine if Concentration Changes were Directly Attributable to Project Operations	Modification of Project Storage and Extraction Operations to Re-establish the Natural Hydraulic Gradient and Background TDS Concentrations at the Margins of the Dry Lakes.
Adverse Impacts to Brine Resources Underlying Bristol and Cadiz Dry Lakes	Groundwater Observation Wells (Cluster Wells at Dry Lakes)	TDS Concentration Changes in Excess of 25% of Background Concentrations in Cluster Wells at the Margins of the Dry Lakes and/or Brine Level Changes of more than 1 ft Above/Below Static Levels in Cluster Wells on the Dry Lakes	TRT to Determine if Concentration Changes or Brine Level Changes were Directly Attributable to Project Operations	Modification of Project Storage and Extraction Operations to Re-establish the Natural Hydraulic Gradient in and at the Margins of the Dry Lakes.
Mobilization of Wind-Blown Dust at Bristol and Cadiz Dry Lakes	Groundwater Observation Wells (Cluster Wells at Dry Lakes), ET Stations (with Soil Moisture Sensors), Open-air, Nephelometers, Digital Cameras, Surface Water Staff Gages, Transmissometer(s) at Class 1 Areas, if warranted.	Water Level Changes of more than 0.5 feet Below Static Water Levels in Wells at ET Stations on the Dry Lakes	TRT to Determine if Level Changes were Directly Attributable to Project Operations	Modification of Project Storage and Extraction Operations to Re-establish the Natural Hydraulic Gradient in and at the Margins of the Dry Lakes.

A generalized decision-making "tree" for the analysis of potential impacts and implementation of project modifications, when appropriate, is presented on Figure 3-10. If an action criterion (defined in Sections 3.7.1 through 3.7.9) were exceeded, the following actions would be initiated. The TRT would analyze all available information, including monitoring data and modeling simulations as described in Section 3.3. Based on this analysis and the criteria defined in Sections 3.7.1 through 3.7.9, the TRT would prepare a recommendation to the BMG which would include one of the following actions: refine Action Criteria, refine the Management Plan monitoring regime, modify project operations, or recommend no action. In all cases, the intent and purpose of a TRT recommendation to the BMG would be to protect Critical Resources.

3.7.1 SPRINGS

3.7.1.1 Potential for Impacts to Springs in the Mojave National Preserve and BLM Managed Lands in the Affected Watersheds

To avoid adverse impacts to springs within the Fenner Valley and Orange Blossom Wash watersheds or groundwater levels beneath the Mojave National Preserve as a result of project operations, and to understand the connection between springflow and groundwater; monitoring of springs and groundwater levels would be conducted as follows: Approximately eight springs (the number of springs may be evaluated by the TRT to increase or decrease the recommended number) would be selected for long-term monitoring (based on Pre-Operational field reconnaissance). In addition, the S-Series observation wells, designed to ensure protection of the springs by measuring groundwater level impacts from project operations and to demonstrate that no impact reaches the Mojave National Preserve or BLM managed lands, would be monitored continuously throughout the term of the Cadiz Project.

Action Criteria:

The decision-making process would be initiated if the Action Criteria were exceeded. The action criteria would be a measured groundwater level change in excess of 1 foot in any of the S-Series observation wells. Such a groundwater level change would be reviewed at the next scheduled TRT meeting or as otherwise determined by a consensus of the TRT. The TRT would determine if the changes were attributable to project operations, as indicated by groundwater level distributions throughout the entire observation well network.

Decision-Making Process (See Figure 3-10):

If the Action Criteria were exceeded, the decision-making process would continue as follows:

- If groundwater level changes exceed the Action Criteria in any of the S-Series observation wells and are not attributable to project operations, as determined by the TRT, then no action, and/or refinement of the Action Criteria would be recommended to the BMG.

- If groundwater level changes exceeded the Action Criteria in any of the S-Series observation wells and were attributable to project operations, as determined by the TRT, then the TRT would assess whether this change would result in an

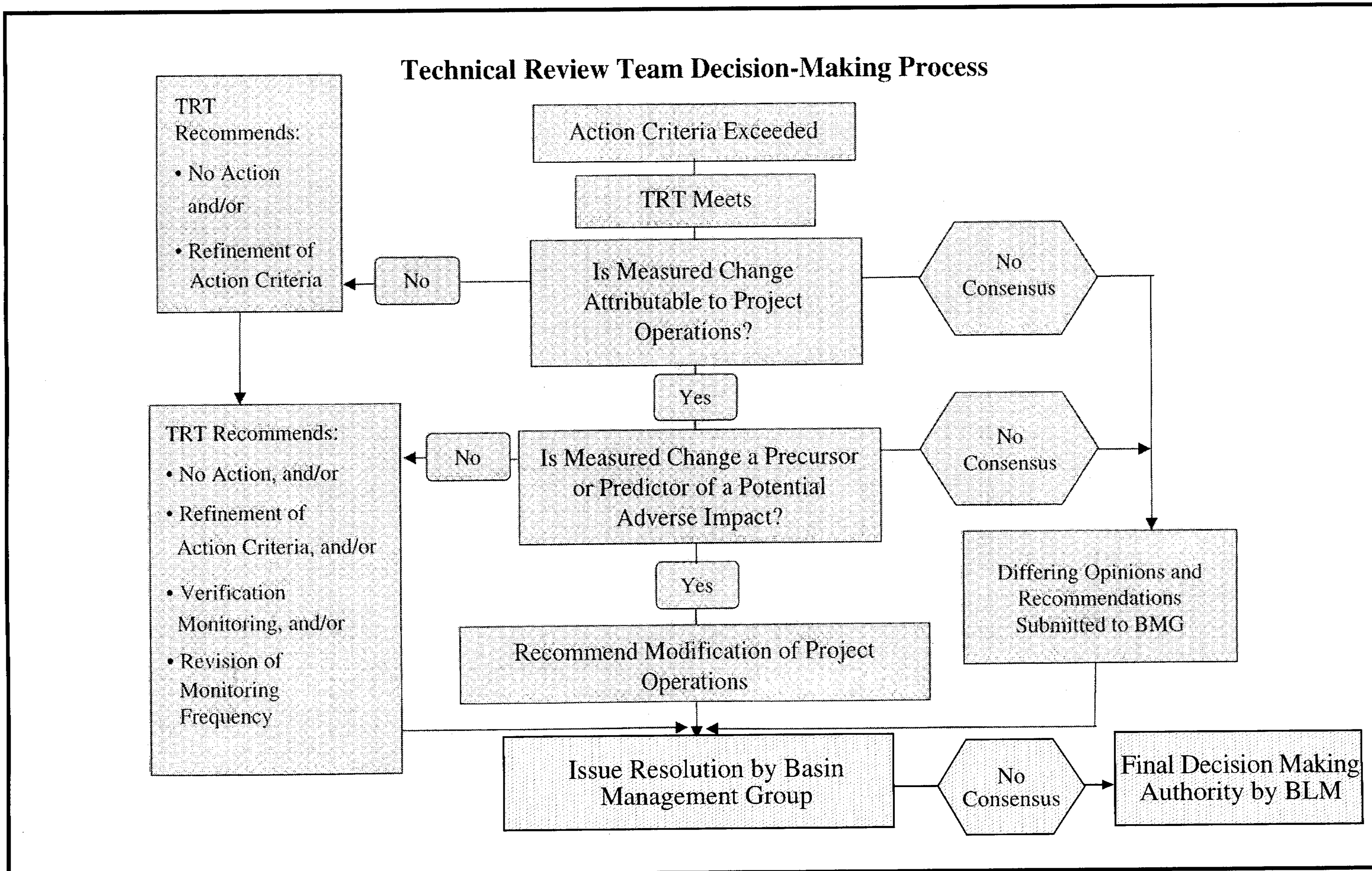


Figure 3-10

Decision-Making Process

adverse impact. Adverse impact includes: (1) the determination that this groundwater level change was predicted to cause a reduction in the flow of any spring; or (2) the determination that this groundwater level change was predicted to cause groundwater level declines at the boundary of the Mojave National Preserve. If no adverse impact were identified, potential recommendations by the TRT would include:

a) No action, or

b) Reevaluation of the location and/or magnitude of the Action Criteria, or

c) Verification monitoring, or

d) Revision of the monitoring frequency at long-term monitoring springs.

- If groundwater level changes exceeded the Action Criteria in any of the S-Series observation wells and were determined to be attributable to project operations, and the TRT concluded that the groundwater level change would result in an adverse impact, then the TRT would recommend the implementation of corrective measures. An adverse impact includes: (1) the determination that this groundwater level change was predicted to cause a reduction in the flow of any spring; or (2) the determination that this groundwater level change was predicted to cause groundwater level declines at the boundary of the Mojave National Preserve.

- If the TRT were unable to reach a consensus regarding:

  a) whether groundwater level changes in any of the S-Series observation wells were attributable to project operations, or

  b) whether groundwater level changes in any of the S-Series observation wells would result in an adverse impact,

  then findings and recommendations would be submitted to the BMG in accordance with the process described in Section 3.9.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of project operations to prevent adverse impacts. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

3.7.2 AQUIFER SYSTEM

3.7.2.1 Potential Impacts to Indigenous Groundwater Quality Due to Project Operations

During storage operations, the quality of Colorado River water in the CRA would be monitored weekly by Metropolitan at Lake Havasu.

Action Criteria:

Corrective measures would be implemented in the event that the quality of the water delivered to the spreading basins does not meet the applicable Basin Plan water quality objectives as determined by the California Regional Water Quality Control Board, Colorado River Basin Region.

Groundwater quality in California is protected pursuant to the California Porter-Cologne Water Quality Control Act. Surface water quality is protected pursuant to the federal Clean Water Act as well as the Porter-Cologne Act. The U.S. Environmental Protection Agency has delegated implementation of water quality provisions of the Clean Water Act to the State of California. In the Cadiz Project area, water quality statutes are administered by the State Water Resources Control Board (State Board) and the California Regional Water Quality Control Board, Colorado River Basin Region (Colorado Regional Board).

Pursuant to these statutes, the Colorado Regional Board prepared and adopted its Water Quality Control Plan in 1994 (Basin Plan) which identifies surface and groundwaters within its geographical jurisdiction, existing and potential future beneficial uses of those waters, and water quality objectives to protect the beneficial uses of the waters. The Basin Plan identifies that the Bristol groundwater hydrologic unit has municipal, industrial and agricultural beneficial uses and that the Cadiz groundwater hydrologic unit has municipal and industrial beneficial uses. The Basin Plan also indicates that Colorado Regional Board's goal is to maintain the existing water quality of all nondegraded groundwater basins.

Additionally, State Board policy states that when existing water quality is better than the quality established in policies, such existing high quality will be maintained until it has been demonstrated to the State that any change will be consistent with the maximum benefit to the people of the State, will not unreasonably affect present and anticipated beneficial use of such water, and will not result in water quality less that described in the policies (Resolution No. 68-16, Statement of Policy with Respect to Maintaining High Quality of Waters in California).

Decision-Making Process:

Colorado River water is used for drinking water, as well as for other municipal, industrial and agricultural beneficial uses. Section 6.2.1 of this document discusses the impacts of the project on the quality of groundwater as a result of introduction of Colorado River water and concludes that they would be less than significant.

Future updates of the applicable Basin Plan may alter the requirements that Cadiz Project operations must meet. Should this occur, the following corrective measures would be implemented under the direction of the regulatory authorities of the California Regional Water Quality Control Board, Colorado River Basin Region.

Corrective Measures:

Corrective measures that would be implemented if the quality of water delivered to the spreading basins does not meet the applicable Basin Plan water quality objectives as determined by the California

Regional Water Quality Control Board, Colorado River Basin Region include:

1. Curtailment of delivery of Colorado River water to the spreading basins, or

2. Provide treatment of the Colorado River water prior to putting it into storage.

3. Implement other corrective measures as required by the California Regional Water Quality Control Board, Colorado River Basin Region.

Responsible Party:

Metropolitan Water District of Southern California

3.7.2.2 Potential Impacts to Wells Owned by Neighboring Landowners Due to Project Operations

It is the intent of the project to operate without impacts to wells owned by neighboring landowners in the vicinity of the project area. To avoid such potential impacts, the groundwater monitoring network would include wells located near such landholdings. Groundwater levels would be monitored on a monthly basis. Water quality would be monitored on a quarterly basis during the Pre-Operational phase and annually thereafter during the term of the Cadiz Project.

Action Criteria:

The decision-making process would be initiated if neighboring landowners submitted written complaints regarding decreased groundwater production yield, degraded water quality, or increased pumping costs.

Decision-Making Process:

If a written complaint were received, Metropolitan would arrange for an interim supply of water to the impacted party. The decision-making process would be as follows:

- If water level changes, decreased yields, increased pumping costs and/or degraded water quality in neighboring landowner wells were not attributable to project operations, as determined by the TRT, then no action would be taken and Metropolitan would discontinue its arrangement to provide water.

- If water level changes, decreased yields, increased pumping costs and/or degraded water quality in neighboring landowner wells were attributable to project operations, as determined by the TRT, then the TRT would make recommendations to perform corrective measures.

- If the TRT were unable to reach a consensus regarding:

  a) whether water level changes, decreased production yields, increased pumping costs, and/or degraded water quality were attributable to project operations, or

  b) what mitigation measure(s) should be recommended,

  then findings and recommendations would be submitted by the TRT to the BMG as described in Section 3.9 and Metropolitan would continue to arrange for a supply water to the neighboring landowner until a decision regarding mitigation could be made.

Corrective Measures:

Upon receipt of the written complaint, and during the decision-making process, Metropolitan would arrange for an interim supply of water to the impacted party as necessary. Additional corrective measures that would be implemented include one or more of the following:

1. Deepen or otherwise improve the efficiency of the impacted well(s);

2. Blend impacted well water with another local source;

3. Construct replacement wells; or

4. Modify project operations until adverse impacts were no longer present at the impacted well(s). Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

3.7.2.3 Potential for Land Subsidence

Twenty benchmarks would be established and surveyed on an annual basis to identify and quantify potential subsidence within the project area (see Figure 3-5). As a result of the land surface subsidence monitoring surveys, an extensometer well may be constructed in areas of known or anticipated subsidence. The extensometer well, if constructed, would verify if the land surface changes (identified from land surveys supplemented with semi-annual InSAR satellite data) were due to (1) subsidence due to groundwater withdrawal or (2) other mechanisms (e.g. regional tectonic movement). Use of predictive modeling of subsidence due to groundwater withdrawal would aid in this analysis.

Action Criteria:

If ground surface elevation were to change more than 0.5 ft within the project area, then the TRT would meet to determine if the subsidence were attributable to project operations. The TRT may recommend the construction of an extensometer well near the center of the subsidence area, or additional InSAR surveys to determine if the subsidence is non-recoverable compaction. The decision-making process would be initiated if non-recoverable compaction attributable to Project operations, as determined from the extensometer well, were to equal or exceed 0.5 ft within the project area.

Decision-Making Process:

If the Action Criteria were exceeded, the decision-making process would be implemented as follows:

- If land surface elevation changes equal to or in excess of the Action Criteria were not attributable to project operations, as determined by the TRT, then no action would be recommended.

- If land surface elevation changes equal to or in excess of the Action Criteria were attributable to project operations, as determined by the TRT, then the TRT would assess whether the subsidence constituted a potential adverse impact to the aquifer. If no such impacts were identified, potential recommendations by the TRT may include:

a) Reevaluation of the Action Criteria,

b) Verification monitoring

c) Revision of the bench mark survey monitoring frequency

- If land surface elevation changes equal to or in excess of the Action Criteria were determined to be attributable to project operations and the TRT concluded that the changes constituted a potential adverse impact in the project area, then the TRT would recommend the implementation of corrective measures.

- If the TRT were unable to reach a consensus regarding:

  a) whether land surface elevation changes were attributable to project operations,

  b) whether land surface elevation changes represented a potential adverse impact, or

  c) what operational modifications were appropriate,

  then findings and recommendations would be submitted to the BMG as described in Section 3.9.

Corrective Measures:

Corrective measures that would be implemented include:

1. Modification of wellfield operations to halt aquifer compaction. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, or (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact.

2. Repair any structures damaged as a result of subsidence attributable to project operations.

Responsible Party:

Metropolitan Water District of Southern California

3.7.2.4 Potential for Increased Risk of Liquefaction Related to Project Spreading Operations

Groundwater levels would be monitored continuously in project area well clusters (Features 5 and 6) in the vicinity of the project spreading basins.

Action Criteria:

The decision-making process would be initiated if groundwater levels, attributable to project operations were measured within 50 feet of the ground surface outside a radius of 500 ft from the boundary of the project spreading basins.

Decision-Making Process:

If the Action Criteria were exceeded, the decision-making process would be implemented as follows:

- If water level rise equaled or exceeded the Action Criteria in the project area observation well clusters but was not attributable to project operations, as determined by the TRT, then no action would be recommended.

- If water level rise equaled or exceeded the Action Criteria in the project area observation well clusters and was attributable to project operations, as determined by the TRT, then the TRT would assess whether the water level rise constituted an increased risk of liquefaction. If no such impacts were identified, recommendations by the TRT may include:

  a) Reevaluation of the Action Criteria, or

  b) Verification monitoring

- If water level rise in the project area observation well clusters was determined to be attributable to project operations and the TRT concluded that the levels constituted an increased risk of liquefaction, then the TRT would recommend the implementation of corrective measures.

- If the TRT were unable to reach a consensus regarding:

  a) whether water level rise in the project area observation well clusters was attributable to Project operations, or

  b) whether water level rise represented an increased risk of liquefaction, or

  c) what operational modifications were appropriate,

  then findings and recommendations would be submitted to the BMG as described in Section 3.9.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of project operations to lower groundwater levels beneath the spreading basins such that the minimum depth to static groundwater was equal to or below 50 feet outside a radius of 500 feet from the boundary of the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

3.7.2.5 Potential for Hydrocompaction Related to Project Spreading Operations

Benchmarks would be established and surveyed on an annual basis to identify and quantify potential hydrocompaction in the immediate vicinity of the project spreading basins.

Action Criteria:

The decision-making process would be initiated if tangible damage (as measured by a 3 foot drop in land surface elevation) attributable to project operations occurred in the immediate vicinity of the project spreading basins.

Decision-Making Process:

If the Action Criteria were exceeded, the decision-making process would be implemented as follows:

- If land surface elevation changes equal to or in excess of the Action Criteria were not attributable to project operations, as determined by the TRT, then no action would be recommended.

- If land surface elevation changes equal to or in excess of the Action Criteria were attributable to project operations, as determined by the TRT, then the TRT would assess whether the subsidence constituted a potential adverse impact to manmade structures in the project area. If no such impacts were identified, potential recommendations by the TRT may include:

  a) Reevaluation of the Action Criteria,

  b) Verification monitoring,

  c) Revision of the bench mark survey monitoring frequency.

- If land surface elevation changes equaling or exceeding the Action Criteria were determined by the TRT to be attributable to project operations and to constitute a potential adverse impact to manmade structures in the immediate vicinity of the project spreading basins, then the TRT would recommend the implementation of corrective measures.

- If the TRT were unable to reach a consensus regarding:

  a) whether land surface elevation changes were attributable to project operations, or

  b) whether land surface elevation changes represented a potential adverse impact to manmade structures in the immediate vicinity of the project spreading basins, or

  c) what operational modifications were appropriate,

  then findings and recommendations would be submitted to the BMG as described in Section 3.9.

Corrective Measures:

Corrective measures that would be implemented include:

1. Repair damage to project spreading basins and related appurtenances due to hydrocompaction.

2. Repair or replace any other facilities in the immediate vicinity of the project spreading basins damaged by hydrocompaction, attributable to project operations.

Responsible Party:

Metropolitan Water District of Southern California

3.7.2.6 Potential for Induced Flow of Lower-Quality Water from Bristol and Cadiz Dry Lakes

A network of "Cluster Type" observation wells would be established between the project wellfield and the margins of Bristol and Cadiz dry lakes (see Figures 3-4 and 3-5). Groundwater TDS concentrations in the well clusters would be monitored on a quarterly basis during the Pre-Operational phase of the Cadiz Project and semi-annually throughout the Operational phase and annually during the Post-Operational phase of the project.

Action Criteria:

The decision-making process would be initiated if TDS concentration changes in excess of 25% of background concentrations occurred in the cluster wells at the margin of the dry lakes and the changes were determined by the TRT to be attributable to project operations. Such a TDS change would be reviewed at the next scheduled TRT meeting or as otherwise determined by a consensus of the TRT.

Decision-Making Process:

If the Action Criteria were exceeded, the decision-making process would be implemented as follows:

- If groundwater TDS concentration changes equal to or in excess of the Action Criteria in the observation well clusters at the margins of the dry lakes were not attributable to project operations, as determined by the TRT, then no action would be recommended.

- If groundwater TDS concentration changes equal to or in excess of the Action Criteria in the observation well clusters at the margins of the dry lakes were attributable to project operations, as determined by the TRT, then the TRT would assess whether the TDS concentration changes constituted a potential adverse impact to (1) the aquifer system, (2) mining operations, or (3) project area production wells. If no such impacts were identified, potential recommendations by the TRT may include:

  a) Reevaluation of the Action Criteria,

  b) Verification monitoring,

  c) Revision of the monitoring frequency of the observation well clusters at the margins of the dry lakes.

- If groundwater TDS changes equal to or in excess of the Action Criteria in observation well clusters at the margins of the dry lakes were determined to be attributable to the project and the TRT concluded that the changes constituted a potential adverse impact to (1) the aquifer system, (2) mining operations, or (3) project area production wells, then the TRT would recommend the implementation of corrective measures.

- If the TRT were unable to reach a consensus regarding:
  a) whether groundwater TDS concentration changes in the observation well clusters at the margins of the dry lakes were attributable to project operations, or

  b) whether groundwater TDS concentration changes represented a potential adverse impact to project area production wells or the aquifer, or
  c) what operational modifications were appropriate,

  then findings and recommendations would be submitted to the BMG as described in Section 3.9.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of project storage and extraction operations to reestablish the natural hydraulic gradient and background TDS concentrations at the margins of Bristol and Cadiz dry lakes. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

3.7.3 BRISTOL AND CADIZ DRY LAKES

3.7.3.1 Potential for Impacts to the Brine Resources Underlying Bristol and Cadiz Dry Lakes

A network of "Cluster Type" observation wells would be established between the project wellfield and the margins of Bristol and Cadiz dry lakes (see Figures 3-4 and 3-5). Groundwater TDS concentrations in the well clusters would be monitored on a quarterly basis during the Pre-Operational phase of the project, semi-annually throughout the Operational phase, and annually throughout the Post-Operational phase of the Cadiz Project. Groundwater levels would be monitored on a continuous basis throughout the term of the project.

Action Criteria:

The decision-making process would be initiated if TDS levels changed in excess of 25% of background levels, or water or brine levels changed by 1 ft from Pre-Operational static levels in the cluster wells at the margins of the dry lakes. Such a TDS or water/brine level change would be reviewed at the next TRT meeting.

Decision-Making Process:

If the Action Criteria were exceeded, the decision-making process would be implemented as follows:

- If groundwater TDS concentration or water/brine level changes equal to or in excess of the Action Criteria in the observation well clusters at the margins of the dry lakes were not attributable to project operations, as determined by the TRT, then no action would be recommended.

- If groundwater TDS concentration or water/brine level changes equal to or in excess of the Action Criteria in the observation well clusters at the margins of the dry lakes were attributable to project operations, as determined by the TRT, then the TRT would assess whether the TDS concentration and/or water/brine level changes constituted a potential adverse impact to brine operations on the dry lakes. If no such impacts were identified, potential recommendations by the TRT may include:

  a) Reevaluation of the Action Criteria,

  b) Verification monitoring,

  c) Revision of the monitoring frequency at the observation well clusters at the margins of the dry lakes,

- If groundwater TDS concentration or water/brine level changes equal to or in excess of the Action Criteria in observation well clusters at the margins of the dry lakes were determined to be attributable to project operations and the TRT concluded that the changes constituted a potential adverse impact to brine operations on the dry lakes, then the TRT would recommend the implementation of corrective measures.

- If the TRT were unable to reach a consensus regarding:

  a) whether groundwater TDS concentration and/or water/brine level changes in the observation well clusters at the margins of the dry lakes were attributable to project operations, or

  b) whether groundwater TDS concentration and/or water/brine level changes represented a potential adverse impact to brine operations on the dry lakes, or

  c) what operational modifications were appropriate,

  then findings and recommendations would be submitted to the BMG as described in Section 3.9.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of Cadiz Project storage and extraction operations to re-establish the natural hydraulic gradient in and at the margins of the dry lakes. Modifications to project operations would include one or more of the following: (a) a reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

3.7.4 AIR QUALITY

3.7.4.1 Potential Impacts to Air Quality due to Dust Mobilization from Water-Level Declines Beneath Bristol and Cadiz Dry Lakes

A network of "Cluster Type" observation wells would be established between the project wellfield and Bristol and Cadiz dry lakes (see Figures 3-4 and 3-5). Groundwater levels would be monitored on a continuous basis throughout the term of the project.

Action Criteria:

The decision-making process would be initiated if groundwater levels changed by 6 inches from Pre-Operational static levels in the cluster wells on the dry lake beds. Such a groundwater level change would be reviewed at the next TRT meeting.

Decision-Making Process:

If the Action Criteria were exceeded, the decision-making process would be implemented as follows:

- If groundwater level changes, equal to or in excess of the Action Criteria in the observation well clusters on the dry lake beds were not attributable to Cadiz Project operations, as determined by the TRT, then no action would be recommended.

- If groundwater level changes equal to or in excess of the Action Criteria in the observation well clusters on the dry lake beds were attributable to project operations, as determined by the TRT, then the TRT would assess whether the groundwater level changes constituted a potential adverse impact to air quality. This would be accomplished by comparing the groundwater level data with data for soil moisture at the lakebed surface, wind velocity data obtained from weather stations on the dry lake beds, and with dust mobilization data obtained from the instrumentation installed up and down wind of Bristol and Cadiz dry lake beds. If no such impacts were identified, potential recommendations by the TRT may include:

    a) Reevaluation of the Action Criteria,

    b) Verification monitoring,

    c) Revision of the monitoring frequency at the observation well clusters on the dry lake beds.

- If groundwater level changes equal to or in excess of the Action Criteria in observation well clusters on the dry lake beds were determined to be attributable to project operations and the TRT concluded that the changes constituted a potential adverse impact to air quality, then the TRT would recommend the implementation of corrective measures.

- If the TRT were unable to reach a consensus regarding:

    a) whether groundwater level changes in the observation well clusters at the margins of the dry lakes were attributable to project operations, or

    b) whether groundwater level changes represented a potential adverse impact to air quality, or

    c) what operational modifications were appropriate,

  then findings and recommendations would be submitted to the BMG as described in Section 3.9.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of project storage and extraction operations to re-establish the natural hydraulic gradient in and at the margins of the dry lakes. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

3.7.4.2 Potential Visibility Impacts to Clean Air Act Class I Areas due to Dust Mobilization at Bristol or Cadiz Dry Lake and Confirmed Presence of Necessary Wind Patterns

Instrumentation installed during the Pre-Operational phase of the project (meteorological towers to the north and south of Bristol and Cadiz dry lakes (Feature

24), open-air nephelometers on the up-wind and down-wind aspects of the dry lakes and digital cameras at the dry lakes (Feature 18) and weather stations (Feature 21)) would provide data on local and regional wind patterns and their ability to transport wind-blown dust from the dry lake beds to a Class I area. Should this data indicate potential to transport any project-mobilized lakebed dust to a Class I area (currently applies to Joshua Tree National Park, but would also apply to Mojave National Preserve if it is designated as a Class I area), then instruments capable of measuring changes in visibility and attributing that change to the Cadiz Project would be installed at the boundaries of the Class I area as discussed in Sections 3.4.2 and 3.5 at Feature 18. An appropriate study design would be developed by the TRT to address necessary instrumentation, data collection protocols, and the location and timing of instrument installation. The Department of the Interior participation in the TRT and BMG would ensure that NPS air quality specialists and appropriate park unit personnel participate in visibility evaluations, development of the study design, and visibility-related recommendations throughout the term of the Management Plan.

In addition to visibility monitoring at the boundaries of Class I areas, any right of way granted by BLM may include conditions necessary or appropriate to provide for visibility monitoring in other locations sensitive to adverse impacts on air quality including, but not limited to Mojave National Preserve.

Action Criteria:

The decision-making process would be initiated if:

a) groundwater level changes equal to or in excess of the Action Criteria at Section 3.7.4.1 in observation well clusters on the dry lake beds were determined to be attributable to project operations and the TRT concluded that the changes constituted a potential adverse impact to air quality, and

b) visibility measurements at the boundary of a Class I area indicate a statistically significant increase, at the 10% significance level, in the seasonal-average light extinction coefficient that exceeds 5% of the seasonal-average baseline value. The tests to be used for statistical significance would be identified by the TRT from analyses of the measurements made at the Class I area boundary during the baseline period.

The decision-making process will also be initiated if BLM determines as part of its right-of-way conditions that the above-described action criteria should be applied to other areas sensitive to adverse impacts on air quality including, but not limited to, Mojave National Preserve.

Decision-Making Process:

If the Action Criteria were exceeded, the decision-making process would be implemented as follows:

- If visibility level changes at the boundary of a Class I area, equal to or in excess of the Action Criteria as measured by the visibility monitoring instruments installed at the boundaries of the Class I area were not attributable to Cadiz Project operations, as determined by the TRT, then no action would be recommended.

- If visibility level changes at the boundary of the Class I area, equal to or in excess of the Action Criteria as measured by the visibility monitoring instruments installed at the boundaries of the park were attributable to Cadiz Project operations, as determined by the TRT, then the TRT would assess whether the visibility level changes constitute an adverse impact on visibility. 'Adverse impact to visibility' is defined at 40CFR52.21(b)(29) as "visibility impairment which interferes with the management, protection, preservation or enjoyment of visitor's visual experience of the Federal Class I area... taking into account the geographic extent, intensity, duration, frequency and time of visibility impairment, and how these factors correlate with (1) times of visitor use of the Federal Class I area, and (2) the frequency and timing of natural conditions that reduce visibility." If no such impacts were identified, potential recommendations by the TRT may include:

  a) Reevaluation of the Action Criteria,

  b) Verification monitoring,

  c) Revision of the visibility monitoring frequency at the boundary of the Class I area.

- If the TRT were unable to reach a consensus regarding:

  a) whether visibility level changes measured at the boundaries of the Class I area were attributable to project operations,

  b) whether visibility level changes constitute an adverse impact on visibility, or

  c) what operational modifications were appropriate,

  then findings and recommendations would be submitted to the BMG as described in Section 3.9.

Corrective Measures:

Corrective measures that would be implemented include:

Modification of project storage and extraction operations to re-establish the natural hydraulic gradient in and at the margins of the dry lakes. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Responsible Party:

Metropolitan Water District of Southern California

3.8 CLOSURE PLAN AND POST-OPERATIONAL REPORTING

3.8.1 CLOSURE PLAN

A Closure Plan would be developed as part of the Management Plan with the objective to ensure that no residual effects of project operations would result in adverse impacts to Critical Resources in or adjacent to the project area.

A Closure Plan would be prepared by Metropolitan with guidance from the TRT when static groundwater levels have declined by 10 feet from Pre-Operational levels. A Closure Plan would be prepared no later than at year 25 of project operations. The Closure Plan would monitor groundwater levels and groundwater quality for a minimum period of 10 years, or as recommended by the TRT and the BMG, to protect Critical Resources and groundwater quality for beneficial uses as required by federal and State law, including the requirements of the California Water Quality Control Board, Colorado Region. The provisions and mitigation obligations under this Management Plan would be in effect and run concurrently with the term of the Closure Plan. Once prepared, the Closure Plan would be reevaluated by the TRT and the BMG every five years. Such reevaluation may include recommendations for refinement of the Closure Plan.

Under this Management Plan, the TRT is required to review and analyze groundwater levels, water quality information, and all other monitoring data; and Metropolitan is required to prepare the annual and five-year reports. One purpose of the five-year reports is to identify any actions that would be taken with the objective to ensure that any decline in Pre-Operational static groundwater levels would not exceed 100 feet at the end of project operations (Closure Groundwater Levels) or lead to projections of exceeding any action level criteria during the Post-Operational phase. Closure Groundwater Levels and static groundwater levels for the five-year reports would be calculated by averaging static groundwater levels in (i) all project area production wells, or (ii) a subset of the project area production wells, as recommended by the TRT and the BMG.

As noted in Sections 1.1 and 3.1.3, all pumping of groundwater in the project area by the Cadiz Agricultural Development would be subject to the provisions of this Management Plan. With the combination of the Cadiz Agricultural Development and the project, there may be declines in static groundwater levels at the termination of project operations. Implementation of the Closure Plan is intended to ensure that the Closure Groundwater Levels are not exceeded and that the groundwater quality would be protected for beneficial uses.

3.8.2 POST-OPERATIONAL REPORTING

The introduction of Colorado River water into the project area could result in an increase in TDS and other constituents, as discussed in section 6.2.1. The project wellfield would be designed to recover all stored Colorado River water, and consequently, any constituents contained in that stored water would be recovered from the basin and pumped to the CRA. Any remaining amounts of stored water in the basin would be small, resulting in insignificant changes to groundwater quality.

Over the term of the project, Metropolitan would operate the program in compliance with the requirements of the Basin Plan issued by the Regional Water Quality Control Board, Colorado River Basin Region. The Regional Board's Basin Plan ensures that beneficial use (municipal, industrial and agricultural) of the basin is maintained for current and future users. During the Post-Operational phase, Metropolitan would collect, analyze and summarize water quality data in a report to confirm compliance with the Regional Board's Basin Plan. These Post-Operational reports would be distributed to the Regional

Board, TRT, BMG, and BLM, and would be available to interested parties upon request.

3.9 TECHNICAL REVIEW TEAM

An integral part of the Management Plan involves regular and on-going review of data collected during the term of the Cadiz Project. A Technical Review Team (TRT) would be established to review data, provide technical interpretations, and make recommendations to the Basin Management Group or BMG.

3.9.1 REPRESENTATION

The TRT would be comprised of representatives from four entities:

1) The Metropolitan Water District of Southern California,

2) Cadiz Inc.,

3) The County of San Bernardino, and

4) U.S. Department of the Interior.

The Interior Department's role on the TRT has not yet been determined, but would likely not be more than an observer. Conflict of interest considerations and compliance with the Federal Advisory Committee Act, P.L. 92-463, support this role.

3.9.2 RESPONSIBILITIES

The TRT would meet as necessary during the Pre-Operational phase to assist in detailed design of the monitoring program. During the Operational phase, the TRT would meet at a minimum on an annual basis, or more frequently as requested by any two members of the TRT to:

- Review data collected during the Operational phase of the Cadiz Project as presented in the annual reports;
- Review models updated with data collected during project operations (to be provided in electronic form with the annual reports);
- Assess and refine Action Criteria for Critical Resources and the methodologies used to determine such criteria (e.g. data and model sensitivity);
- Review potential adverse impacts to Critical Resources;
- Review Closure Plan; and
- Develop recommendations to the BMG.

3.9.3 ANNUAL AND FIVE-YEAR MONITORING REPORTS

As the annual and five-year monitoring reports would include electronic copies of all monitoring data, model runs and model input and output data, the TRT would have the opportunity to review these models and data in performing their review of project operations. Data would be made available to the TRT through an electronic network (e.g. Web Page) or other appropriate means to enable regular updates on Cadiz Project operation and management activities.

3.9.4 RECOMMENDATIONS TO THE BASIN MANAGEMENT GROUP

Annual TRT recommendations to the BMG would be determined by consensus opinion of the TRT. Recommended actions may include:

- changes to the number of monitoring features,

- changes in monitoring frequency,
- changes in monitoring technology,
- refinements of Action Criteria for Critical Resources,
- modification of the Management Plan,
- revisions to the Closure Plan, and/or
- changes in operations of the Cadiz Project if any Action Criteria (as defined in Sections 3.7.1 to 3.7.9) were exceeded.

In the event that a consensus between TRT entities was not reached, all views and recommendations would be presented to the BMG for resolution.

3.10 BASIN MANAGEMENT GROUP

The BMG would be established to resolve issues related to TRT recommendations and to implement this Management Plan. If the BMG does not reach consensus, the BLM would retain ultimate control over the enforcement of the terms and conditions of any right-of-way grant(s) it issues.

3.10.1 REPRESENTATION

The BMG would be comprised of representatives from four entities:

1) The Metropolitan Water District of Southern California,

2) Cadiz Inc.,

3) The County of San Bernardino, and

4) U.S. Department of the Interior.

The Interior Department's role on the BMG has not yet been determined, but would likely not be more than an observer. If the BLM were to be a member of the BMG, the group may need to be constituted as an advisory committee under the Federal Advisory Committee Act, P.L. 92-463. Moreover, having BLM serve as a member of a body that resolves issues relating to TRT recommendations could raise conflict of interest problems since the BMG would then include regulated parties as well as the regulator (BLM).

3.10.2 RESPONSIBILITIES

The BMG would meet at a minimum on an annual basis, or more frequently if requested. The BMG would provide oversight to ensure that the Cadiz Project does not significantly impact Critical Resources in accordance with this Management Plan, including the following:

- Review annual and five-year reports prepared by MWD under the Management Plan;
- Review background information, monitoring data and modeling tools submitted to the BMG by the TRT under the Management Plan;
- Review and revise, and adopt or reject, recommendations made by the TRT for the refinement of Action Criteria, the amendment of the Management Plan, and the modification of project operations;
- Modify project operations to protect Critical Resources and to prevent potential and actual adverse impacts from Project operations;

- Review and revise the Closure Plan for the Cadiz Project; and
- Refer matters pertaining to the Management Plan and project operations to the TRT for analysis and recommendation.

3.10.3 DECISION-MAKING PROCESS

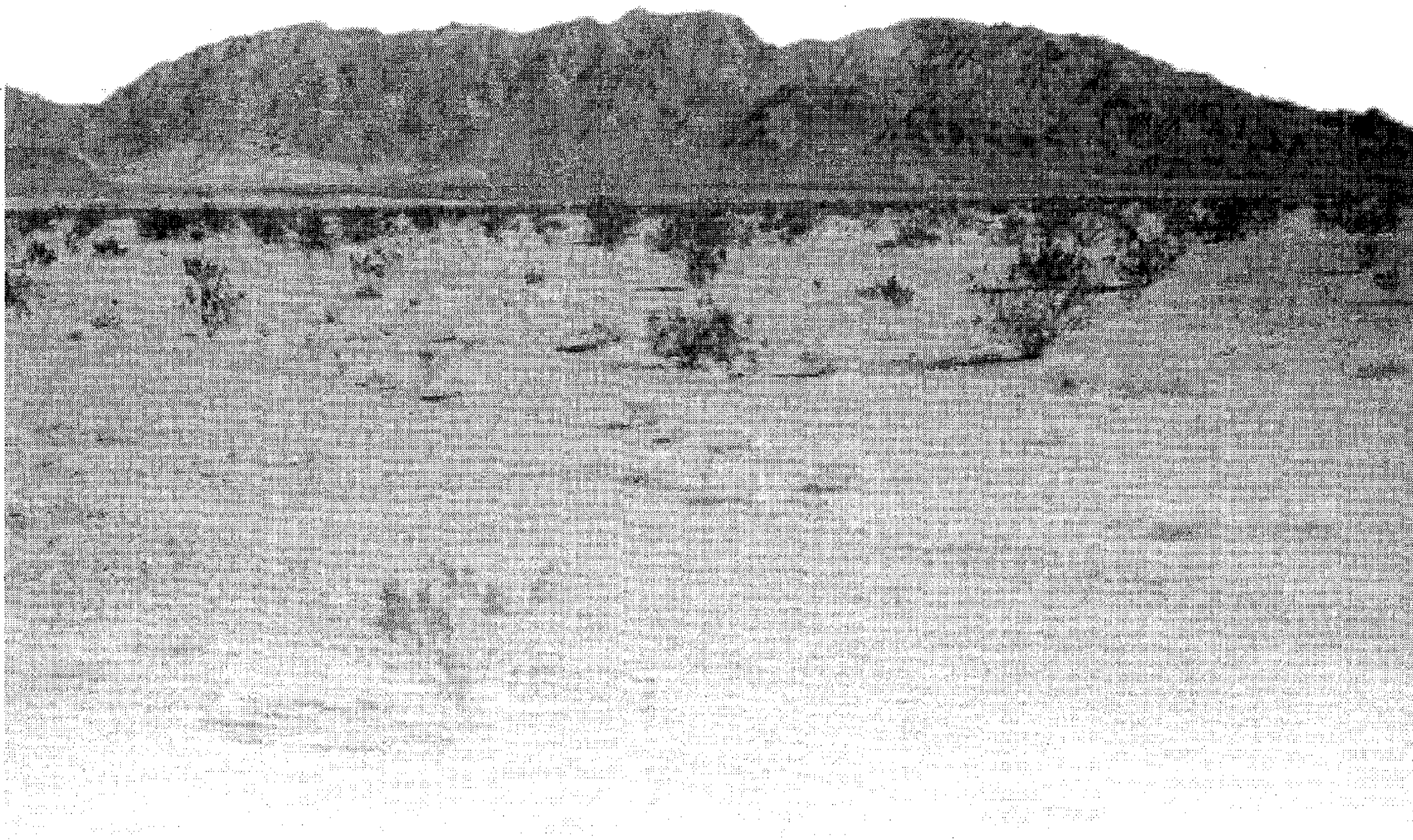
The oversight activities of the BMG are intended to be exercised through developing a consensus of all of the Parties. Whenever the BMG receives recommendations from the TRT, with or without unanimous approval, the members would confer in good faith to review and evaluate the recommendations developed by the TRT and any relevant data and technical interpretations under the Management Plan, resolve any disparate views of the members of the TRT, and reach a consensus for the disposition of the TRT recommendations.

If consensus cannot be reached by the members on the appropriate action to be taken based upon the recommendation(s) received from the TRT, use of an independent facilitator may be utilized by the BMG to assist in developing a consensus decision. If consensus cannot be reached by the BMG, then BLM would retain ultimate control over the enforcement of the terms and conditions of any right-of-way grant(s) it issues.

Prior to the publication of the Final EIR/EIS, the details of the structure and function of the TRT and BMG relative to implementing the Management Plan will be developed. Regardless of how these specifics develop, the BLM would retain ultimate control over the enforcement of the terms and conditions of any right-of-way grant(s) it issues.

SECTION 4.0

CEQA Thresholds of Significance



SECTION 4.0

SECTION 4.0
CEQA THRESHOLDS OF SIGNIFICANCE

The California Environmental Quality Act (CEQA) requires that the CEQA Lead Agency state in the EIR the thresholds at which potential adverse impacts will be considered significantly adverse to the environment for purposes of environmental review. These thresholds are determined by the Lead Agency and guide the Lead Agency in its consideration of a proposed action by prescribing quantitative or qualitative standards or a set of criteria which would normally constitute a significant adverse impact on the physical environment. The CEQA Guidelines, regulations that implement the CEQA statute, provide a check-list of the kinds of effects that may be considered to be potentially significant. As the CEQA Lead Agency for the Cadiz Project, Metropolitan has tailored these suggested significance categories in the CEQA Guidelines to specifically address the Cadiz Project and has used them to evaluate the effects of the project on the environment.

The significance thresholds listed below have been used to evaluate the Cadiz Project with respect to effects that are related to water resources. In Section 6.0 of this Supplement, each potential effect of the project is discussed and a determination is made as to whether the effect of the project would be significant. In this Supplement, the Management Plan has been incorporated into the project and potential effects are reviewed in light of implementation of the Management Plan.

In Section 3.0, the Management Plan identifies Critical Resources, potential adverse impacts of the Cadiz Project on the Critical Resources and action criteria which, if reached, may indicate that an adverse impact may occur as a result of the project. Because the Management Plan has been developed to predict and avoid significant adverse effects, the potential adverse impacts and the action criteria have been set conservatively and would be triggered well in advance of the occurance of a *significant* adverse effect as identified by the CEQA significance thresholds listed below.

A project is normally considered to have a significant adverse impact on surface water or groundwater flow, groundwater supply, groundwater levels, groundwater quality, or air quality if it results in:

- The violation of any drinking water quality standards or waste discharge requirements, including those in the California Regional Water Quality Control Board's Colorado River Basin Region.

- Substantial depletion of groundwater supplies or substantial interference with groundwater recharge, such that there would be a net deficit in aquifer volume or a lowering of the local groundwater table to the extent that existing nearby well production would not support existing land uses or planned uses for which permits have been granted.

- Substantial fluctuations in brine levels on Bristol or Cadiz dry lakes resulting in significantly reduced production at the salt-mining operations on the dry lakes.

- Substantial alteration of the existing drainage pattern of a site or area, including the alteration of the course of a stream or river, in a manner which would result in substantial erosion or siltation on- or off-site.

- Substantial increase of the rate or amount of surface runoff in a manner which would result in flooding on- or off-site.

- Creation or contribution of runoff water that would exceed the capacity of existing or planned stormwater drainage systems or providing substantial additional sources of polluted runoff.

- Structures placed within a 100-year flood hazard area which would impede or redirect flood flows.

- Exposure of people or structures to a significant risk of loss, injury or death involving flooding, including flooding as a result of the failure of a project facility, such as a spreading basin or pipeline.

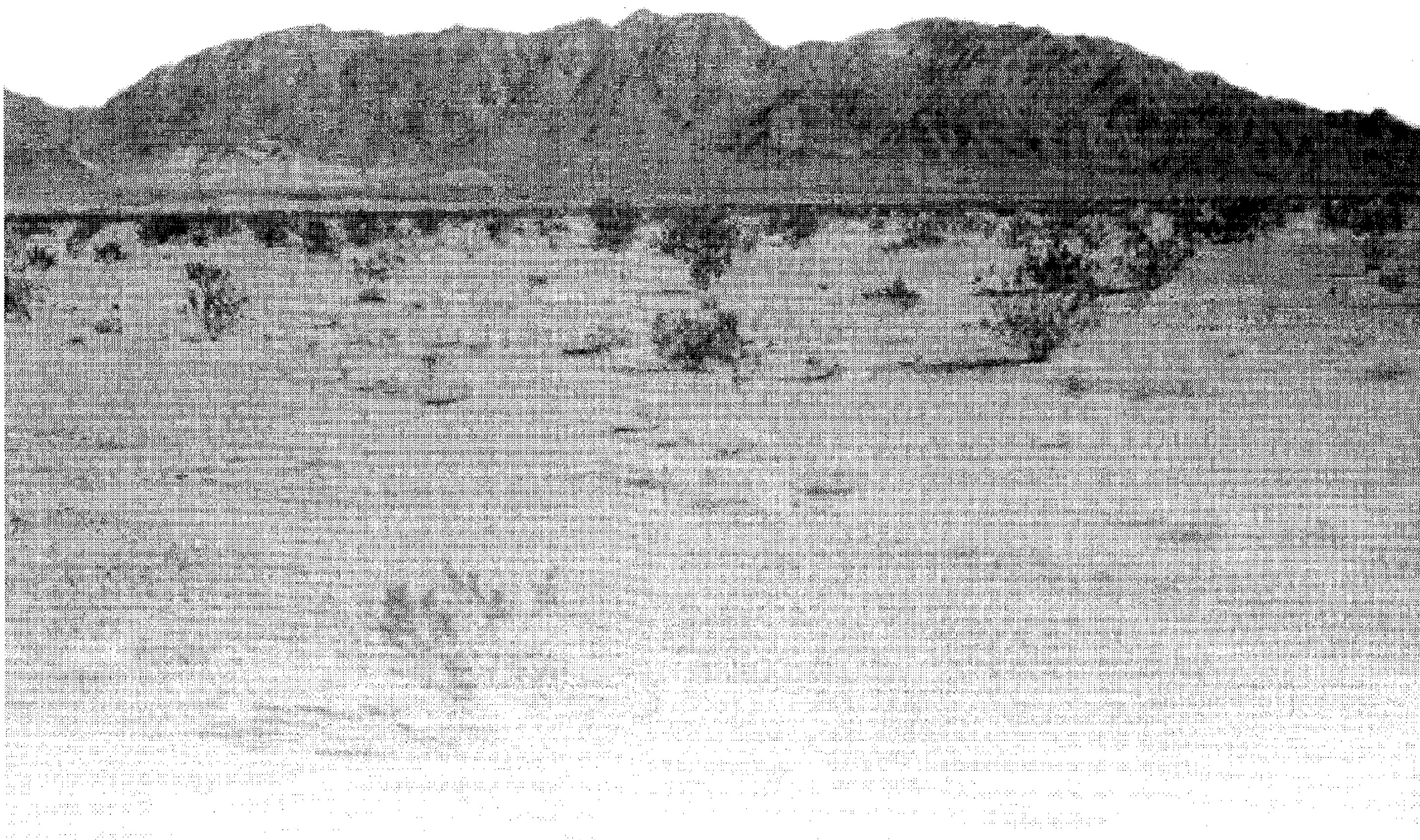
- Substantial increases in ground instability in the project area, including subsidence, hydrocompaction, or increased risk of liquefaction.

- Substantially increased mobilization of dust from Bristol or Cadiz dry lakes during periods of high wind.

- Drawdown of groundwater within the boundary of the Mojave National Preserve or BLM-managed lands within the affected watersheds that results in substantial adverse impacts to springs.

- Inundation by a seiche, tsunami or mudflow.

SECTION 5.0
Methodology



SECTION 5.0

SECTION 5.0
METHODOLOGY

Section 5.5.3 of the November 1999 Draft EIR/EIS discusses the collection of field data, implementation of pilot spreading basins, and modeling that were used to assess the feasibility of storing large quantities of Colorado River water beneath the Fenner Gap portion of the project area and to analyze potential impacts of the Cadiz Project on environmental resources including ground structure stability, water quality, and microclimate of the Fenner Gap. These studies involved the collection of extensive geologic, hydrologic, and water quality data in the Cadiz Project area including: 1) collection of background data regarding the geology and hydrogeology of the groundwater aquifer system underlying the project area; 2) collection of field data on soil/rock types, groundwater levels, aquifer characteristics and water quality in the project area; 3) construction and operation of an infiltration test using two 2.5-acre pilot spreading basins located within the area of the proposed project spreading basins; and 4) development of water quality mixing models to assess the effects of mixing Colorado River water with indigenous groundwater.

Because of technical disagreement regarding the groundwater flow modeling used in the Draft EIR/EIS, the six operational scenarios presented in the Draft EIR/EIS are no longer being utilized to evaluate potential impacts of the proposed project. The Management Plan presented in Section 3.0 of this Supplement has replaced the use of the operational scenarios and has been incorporated into the proposed action. The Management Plan would require measurement of physical parameters at key locations throughout the potentially affected region for early detection of changes to groundwater levels, groundwater quality, and air quality related to mobilization of dust from the dry lake beds. Data obtained from physical monitoring facilities would be used to calibrate models that would be used to predict behavior of the affected aquifers and surface water features. Early modifications to project operations dictated by the Management Plan would avoid impacts that could be caused by the project. Impacts are evaluated in Section 6.0 of this Supplement assuming implementation of the Management Plan.

5.1 COLLECTION OF FIELD DATA

The field studies provide valuable information that continues to be used in the analyses presented in this Supplement. Seven shallow boreholes were drilled in the Fenner Gap portion of the project area to assess soil types and variations in subsurface stratigraphy. Eleven groundwater monitoring wells were drilled and installed in the Fenner Gap portion of the project area to monitor water levels and facilitate collection of water quality data. Monitoring wells were installed in and adjacent to the pilot spreading basins and soil moisture sensors were installed to monitor vertical movement of infiltrating water through the unsaturated zone beneath the pilot test basins. A production well was drilled in the Fenner Gap to serve as a source of water for the pilot spreading basin test as well as a test of the well design for the project wellfield.

5.2 PILOT SPREADING BASINS

The pilot spreading basin test was performed to determine the feasibility of storing

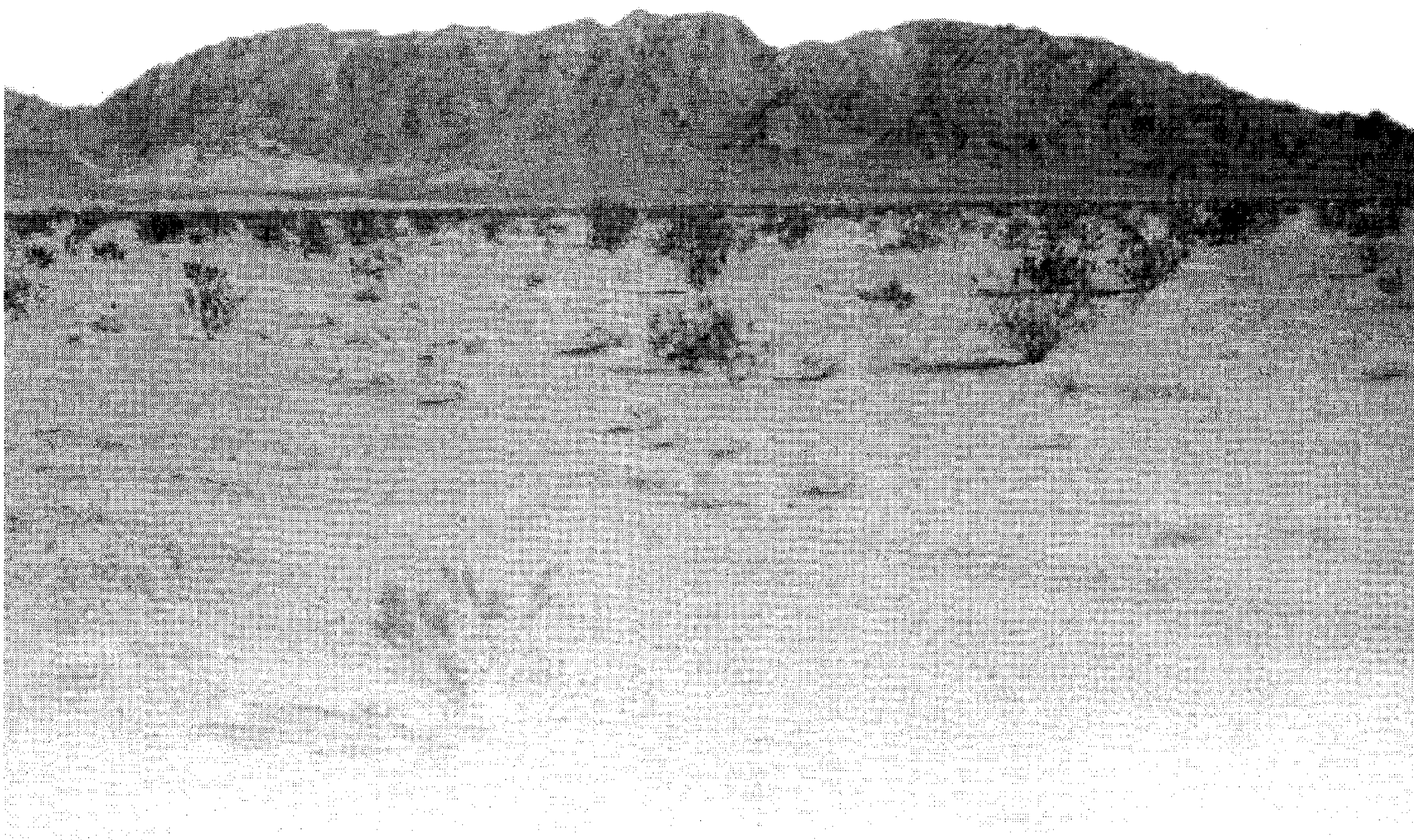
Colorado River water in, and later retrieving it from, the aquifer system underlying the Fenner Gap portion of the project area. The pilot test program was also designed to assess the types and extent of environmental impacts that could potentially result from implementation of the Cadiz Project. The pilot spreading basin consists of two 2.5 acre cells. The pilot basin is operated by pumping water from a production well via a temporary pipeline into one of the cells. Spreading tests were performed to evaluate the infiltration rate of percolating water to determine the dimensions of the resulting mound of elevated groundwater that forms as a result of surface spreading, and to monitor any changes to water quality during the spreading test. A weather station and an evaporation pan located at the pilot spreading basin collected data on wind speed and direction, precipitation, air temperature, relative humidity and evaporation rates.

5.3 WATER QUALITY MIXING MODEL

The water quality mixing model used laboratory tests and a physical scale model of the affected portion of the aquifer to evaluate the chemical effects of mixing Colorado River water with indigenous groundwater underlying the Fenner Gap part of the project area. The laboratory model takes into account various environmental factors, including soil chemistry, indigenous water temperature, and potential biological impacts. The results of the physical model were verified using a computer model to simulate the mixing of waters of different composition (Parkhurst & others 1980).

SECTION 6.0

Water Resources Impacts and Mitigation



SECTION 6.0

SECTION 6.0
WATER RESOURCES IMPACTS AND MITIGATION

As described in Section 3.0, the Management Plan would provide guidelines for assessment and management of Cadiz Project operations. All project operations would comply with the provisions and requirements of the Management Plan for the purposes of avoiding or minimizing adverse impacts that could potentially result from the project. The "project area" under the provisions of the Management Plan refers to the area encompassing the proposed recharge and extraction facilities and existing Cadiz agricultural wellfield located within the Fenner Gap area. During storage operations, the surface of the water table underlying the project spreading basins would rise (mound) in response to the infiltration of the imported Colorado River water. During extraction operations, a depression would form in the water table underlying the project wellfield. During storage operations, Colorado River water, which is of a different quality than local groundwater, would blend with indigenous groundwater. Project operations could result in potential impacts to the following resources:

- Spring flow due to fluctuation of groundwater levels

- Aquifer system

  - Groundwater quality and recharge capacity due to project operations
  - Neighboring wells due to groundwater level fluctuations
  - Ground structure (land subsidence, increased risk of liquefaction, and settlement from hydrocompaction)
  - Long-term drawdown of groundwater

- Brine resources of Bristol and Cadiz dry lakes

- Air quality related to mobilization and transport of lakebed dust to Joshua Tree National Park, Mojave National Preserve and BLM-Managed Lands.

- Water quality in the CRA due to introduction of indigenous groundwater

- Fenner Gap microclimate modifications

- Desert environment due to implementation of the Management Plan.

6.1 POTENTIAL IMPACTS TO SPRING FLOW DUE TO FLUCTUATION OF GROUNDWATER LEVELS

The closest boundaries of the Mojave National Preserve are located approximately 15 miles north of, and up-gradient from, the proposed project spreading basins and wellfield. There is continuity between the aquifer systems underlying the project area and some parts of the Mojave National Preserve. Because groundwater levels underlying the Mojave National Preserve are considered a Critical Resource, the Management Plan includes specific provisions to prevent any adverse impacts to groundwater levels or springs located within the Mojave National Preserve, or to springs located within BLM-managed lands.

No springs are known to exist in the project area. The closest spring (Bonanza Spring located on BLM-managed land) is located in the Clipper Mountains approximately 12 miles north of the proposed spreading basins and wellfield. Other springs in the region are located in the Granite and Old Woman mountains. These springs range in distance from 15 to 20 miles from and are up-gradient of the project area. Springs located within the Mojave National Preserve, federally designated Wilderness Areas, and Bonanza Spring are identified in the Management Plan as Critical Resources. A comprehensive program for monitoring and preventing any adverse impact to such springs has been prepared.

An inventory of springs within the Fenner and Orange Blossom Wash watersheds would be prepared as part of the Management Plan. During the Pre-Operational phase of the project, approximately eight springs would be selected as long-term monitoring sites. These sites would be monitored to further evaluate the recharge characteristics affecting the springs and determine whether fluctuations of spring flow are caused by project operations or natural variation.

S-Series observation wells would be located between the project area and springs and would serve as an "early warning system" by providing outpost monitoring of potential water level changes as a result of project operations. If water level changes in excess of one foot occur at these S-Series observation wells, these changes would be evaluated in accordance with the provisions of the Management Plan. Corrective measures (Section 3.7) that would be implemented, as appropriate, would entail modification of project operations to prevent adverse impacts. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins. Accordingly, the potential impacts to springs as a result of project operations are determined to be less than significant.

6.2 POTENTIAL IMPACTS TO AQUIFER SYSTEM

6.2.1 POTENTIAL IMPACTS TO GROUNDWATER QUALITY OR THE RECHARGE CAPABILITY OF THE PROJECT SPREADING FACILITIES DUE TO INTRODUCTION OF COLORADO RIVER WATER

Potential changes in groundwater quality or the recharge capability of the project spreading facilities would occur as a result of introducing Colorado River water into the groundwater basin underlying the project area. These changes would include: 1) transport of salts from the unsaturated zone into the indigenous groundwater, 2) introduction of undesirable constituents, such as TDS and perchlorate, from Colorado River water; and, 3) precipitation of minerals (primarily calcium carbonate) within the sediments that make up the aquifer system.

Based on results obtained during operation of the pilot spreading basin and groundwater analyses from the nearby observation wells, the initial infiltration of Colorado River water during project spreading operations is expected to dissolve salts in the upper parts of the unsaturated zone and carry them downward to the water table (Metropolitan 1999b). Although this process would create some initially high TDS concentrations in groundwater immediately below and adjacent to the spreading basins, over time the effect would be transitory because the dissolved salts would be pumped out or assimilated into the groundwater within the project area and would not impact wells outside the project area. Accordingly, such impacts are less than significant.

The introduction of Colorado River water (approximately 600 mg/L TDS) into indigenous groundwater in the project area (approximately 300 mg/L TDS), would result in an increase in groundwater TDS concentrations. It is anticipated that this effect would be limited to the area of groundwater mounding caused by the project spreading operations. Any introduced Colorado River water would most likely be removed by the project wellfield during extraction operations. To recover stored Colorado River water from the basin, selected production wells would be screened in the more permeable upper alluvial sediment (current unsaturated zone). This design feature would allow for extraction of stored water that contains greater concentrations of TDS than the indigenous groundwater. Any remaining increase in TDS concentrations within the project area groundwater would be small and would not affect compliance with State and federal drinking water standards or other beneficial groundwater uses (municipal, industrial and agricultural) in or adjacent to the project area. Further, to ensure that neighboring wells would not be significantly impacted, the Management Plan (Section 3.7) prescribes specific provisions including curtailment of delivery of Colorado River water to the spreading basins.

In addition, perchlorate has been identified in Colorado River water and would impact the water quality of the indigenous groundwater in the Cadiz Project area. Recent testing has detected this constituent in Colorado River water at concentrations ranging from non-detectable to as high as 9 micrograms/liter (μg/L). The current provisional State of California Department of Health Services maximum contaminant level for perchlorate is 18 μg/L.

Any increased perchlorate concentrations that may occur in the project area would be in compliance with drinking water standards. However, the Management Plan provides (Section 3.7) for specific corrective actions should perchlorate concentrations affect any neighboring wells. Such corrective actions include improving impacted wells, blending impacted well water with other local sources, modifying project operations, or constructing replacement wells. It is anticipated that most of this perchlorate would be pumped back to the CRA during withdrawal operations. As a result, it is not expected that an increase in perchlorate concentrations within the project area groundwater would adversely affect beneficial groundwater uses (municipal, industrial and agricultural) in or adjacent to the project area. Accordingly, these adverse impacts would be less than significant.

Potential changes in groundwater quality may occur in the event that operation of the project wellfield induced migration of water from the deeper aquifer zones underlying the project area. However, as this deeper aquifer is not characterized, information regarding water quality from the deeper zones is not available. Deep exploratory drilling and water quality sampling conducted under the guidance of the TRT in development of the project wellfield would provide site-specific information regarding water quality variation with depth in the project area. This information would be used to site and design production wells in order to avoid or minimize potential water quality impacts. Based on the more than 16 years of pumping history of the Cadiz agricultural wells, no significant changes in water quality have been observed. Accordingly, potential adverse impacts to groundwater basin water quality due to migration of water from the deeper aquifer zones are anticipated to be less than significant.

During spreading operations, the mixing of Colorado River water and indigenous groundwater could potentially result in the precipitation of minerals (primarily calcium carbonate) within the sediments that make up the aquifer system in the vicinity of the spreading basins. Such precipitation could, by decreasing the porosity of the aquifer, reduce the recharge capability of the project spreading facilities. The results of extensive laboratory testing and computer modeling indicate that the mixture of the two waters is near equilibrium with respect to minerals present and concludes that significant precipitation of minerals under the geochemical conditions modeled would not occur. (Metropolitan 1999b) As a result, it is concluded that this effect would be highly unlikely and limited in its areal extent. Accordingly, the potential impacts would be less than significant.

6.2.2 POTENTIAL IMPACTS TO NEIGHBORING WELLS DUE TO GROUNDWATER LEVEL FLUCTUATIONS

The communities nearest the project area are Chambless (six miles), Amboy (15 miles), Essex (20 miles) and the cities of Twentynine Palms (40 miles) and Needles (60 miles). The locations of these communities in relation to the project area are shown on Figure 2-14.

The community of Chambless, located approximately six miles from Fenner Gap, is underlain by groundwater that is in hydraulic continuity with that of the project area. As a result, there is potential for project groundwater operations to impact wells in the Chambless area. To ensure that there would be no significant adverse impacts to wells located in the community of Chambless, the Management Plan includes specific provisions (Sections 3.6 and 3.7) to monitor wells in the area and to modify project operations if necessary. As a result, adverse impacts to wells in the community of Chambless would be less than significant.

The community of Amboy, which is located north of Bristol Dry Lake, is separated from the project area by brine-saturated sediments and salt deposits underlying Bristol Dry Lake. Consequently, there is no potential for continuity of potable groundwater in the project area with groundwater beneath this community.

The community of Essex is located in Fenner Valley, approximately 20 miles up-gradient from the project spreading basins and wellfield. Although there is continuity between the aquifer systems underlying the project area and Essex, all the wells in the Essex area are located beyond and up-gradient of what is anticipated to be the maximum area of influence of project operations. To ensure that there would be no significant adverse impacts to wells located in the community of Essex, the Management Plan includes specific provisions (Sections 3.6 and 3.7) to monitor wells in the area, and to modify project operations if necessary.

The project area is separated from groundwater in the Twentynine Palms area by at least 30 miles. Nearly eight miles of this distance is occupied by the brine-saturated sediments and salt deposits of Bristol Dry Lake, which reach depths of more than 6,000 feet. Furthermore, the project area is separated from Twentynine Palms by crystalline basement rock exposed in the Bullion Mountains. The Bullion Mountains exceed 4,000 feet in elevation and are located on the southwest side of Bristol Dry Lake, creating a barrier to the transmission of groundwater. Accordingly, there is no potential for groundwater continuity or flow between the project area and Twentynine Palms, thus there would be no impacts due to project operations.

Groundwater in the vicinity of Needles and the Colorado River is separated from the project area by 60 miles, including intervening mountain ranges of crystalline basement rock, which reach elevations in excess of 5,000 feet. Similar to the case of groundwater in the Twentynine Palms area, there is no potential for groundwater continuity or flow between the project area and either the town of Needles or the Colorado River. Consequently, there would be no impact due to project operations.

Within the project area, the greatest potential for impact due to groundwater mounding and depression is in the vicinity of the project spreading basins and wellfield. As specified in the Management Plan (Section 3.6), static groundwater levels would be monitored regularly beginning in the Pre-Operational phase (the period from the publication of the Records of Decision and Notice of Determination until the completion of facilities necessary to store water; approximately 15 to 24 months), throughout the Operational phase and through the Post-Operational phase (10 years following the cessation of project operations, or a time period as otherwise determined by the BLM). Groundwater levels would be monitored continuously using downhole pressure transducers in designated wells described in the Management Plan.

The project observation well network may be supplemented with a network of microgravity stations located in the immediate project vicinity. The microgravity stations would measure changes in the depth to groundwater by identifying subsurface density differences between saturated and unsaturated soils. This supplemental microgravity data could be used in conjunction with water levels measured in observation wells.

If neighboring landowners submit written complaints regarding decreased groundwater production yield, degraded water quality, or increased pumping costs, and it is determined by the TRT that these effects are attributable to the project, these changes would be evaluated in accordance with the provisions of the Management Plan.

To ensure that there would be no significant adverse impacts to long-term groundwater levels due to project operations, corrective measures would be implemented. Corrective measures include the following: deepen or otherwise improve the efficiency of the impacted well(s); blend impacted well water with another local source; construct replacement wells; or modify project operations until adverse impacts were no longer present at the impacted well(s). Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins. Implementation of the Closure Plan would be designed to ensure that static groundwater levels would not be depressed by more than 100 feet at the end of the project Operational phase. In addition the overall purpose of the Closure Plan is to (1) ensure that no residual effects of project operations would result in adverse impacts to Critical Resources in or adjacent to the project area and (2) protect groundwater quantity and quality for future beneficial uses in and adjacent to the project area. These limitations together with all other provisions of the Management Plan would protect groundwater resources within the project area. Accordingly, adverse impacts to groundwater levels as a result of project operations would be less than significant.

6.2.3 POTENTIAL FOR LAND SUBSIDENCE

The area with the greatest potential for subsidence is in the western part of the project wellfield in the vicinity of the Cadiz Inc. agricultural operations. This area contains the highest proportion of fine-grained sediments observed in the subsurface, below the water table. Railroad lines owned and operated by BNSF and Arizona California Railroad (ARZC), and natural gas and crude oil pipelines operated by El Paso Natural Gas Co. and Questar cross part of this area.

The Management Plan provides that during the Pre-Operational phase approximately 20 survey benchmarks would be installed at appropriate locations within the area of the project wellfield. Benchmark surveys would be conducted on an annual basis during all phases of the project. In addition to the benchmark surveys, InSAR data may be obtained for the project area, if appropriate. The InSAR data would be used to monitor relative changes of land surface elevation that could be related to aquifer system deformation in the project area and would complement the land survey data to establish changes in land surface elevations.

In addition, an extensometer well may be constructed within the area of the highest probability of subsidence pending results of the annual benchmark surveys and evaluation of InSAR data. The extensometer would be constructed to measure non-recoverable compaction of fine-grained materials interbedded within the alluvial aquifer systems.

If this field monitoring determines that project operations caused a surface elevation change of 0.5 feet within the project area, all relevant information would be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented as appropriate include modification to project operations. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins. Accordingly, the anticipated impact of subsidence as a result of project operations is determined to be less than significant.

6.2.4 POTENTIAL FOR LIQUEFACTION

Liquefaction is the transformation of water-saturated granular material (usually sand or sand/silt mixtures) from a solid state to a liquid state as a result of increased pore water pressure during intense ground shaking, as from a major earthquake. When undergoing liquefaction, surface soils can be transformed into a state that would no longer support structures. Liquefaction is generally considered a risk where fine-grained sediments are saturated by groundwater to within 50 feet of the ground surface. The most shallow groundwater levels anticipated during the project storage operations would be approximately 80 feet below ground surface. As outlined in Section 3.6 of the Management Plan, groundwater levels would be continuously monitored in the vicinity of the project spreading basins during spreading operations, and shallow groundwater levels would be avoided by modification of project operations. Should groundwater levels attributable to project operations be measured within 50 feet of the ground surface outside a radius of 500 feet of the boundary of the project spreading basins, these groundwater level changes would be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented, as appropriate, would include modifications to project operations. These modifications would include halting of any on-going spreading operations or pumping of groundwater to reduce groundwater levels to below the action criterion level above. Accordingly, an increase in the risk of liquefaction would be less than significant.

6.2.5 POTENTIAL FOR HYDROCOMPACTION

Hydrocompaction refers to the settlement of sediments as a result of the saturation, displacement, and consolidation of the mineral grains within the sediments. Hydrocompaction generally affects the upper 20 feet of sediments and does not usually exceed 12 inches in total vertical settlement. The part of the project area that could be affected by settlement due to hydrocompaction is limited to the area to be occupied by the project spreading basins. It is not anticipated that project operations would result in hydrocompaction impacts to railroad tracks, pipelines, local residents, agricultural operations or any other entity.

Annual benchmark surveys would be used to identify and quantify potential hydrocompaction in the immediate vicinity of the project spreading basins. If it were determined through monitoring that project operations resulted in a change of surface elevation of 3 feet in the immediate vicinity of the project spreading basins, all relevant information would be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented, as appropriate, are described in the Management Plan (Section 3.6). These corrective measures include repair of damage to spreading basins and related appurtenances and repair or replacement of any other facilities in the immediate vicinity of the spreading basins damaged by hydrocompaction attributable to project operations. Accordingly, potential hydrocompaction impacts would be less than significant.

6.2.6 POTENTIAL FOR INDUCED FLOW OF LOWER QUALITY WATER FROM BRISTOL AND CADIZ DRY LAKES

Migration of lower-quality groundwater into the project area from the dry lakes is not likely to result from project extraction operations. With the exception of saline groundwater beneath and adjacent to the dry lakes, water quality is relatively consistent throughout the region as shown in Figure 2-13. Groundwater TDS concentrations in the vicinity of the dry lakes are higher than those found in the Fenner Gap. However, the influence of the project wellfield in the vicinity of the dry lakes would be slight, and accordingly, the migration of the saline interface into the project area would be minimal.

The location of the saline groundwater interface (defined by the 1,000 mg/L TDS concentration line) was determined using recent groundwater data from wells in the vicinity of the project area. Regular monitoring of potential movements of this saline groundwater interface would be undertaken as part of the Management Plan. Monitoring would be accomplished with a network of cluster wells established between the project wellfield and the margins of Bristol and Cadiz dry lakes. Should project operations cause the TDS concentrations to change in excess of 25 percent of background concentrations in these cluster wells, these changes would be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented, as appropriate, would include modification of project storage and extraction operations to re-establish the natural hydraulic gradient and background TDS concentrations at the margins of Bristol and Cadiz dry lakes. As a result, potential adverse impacts to users of the fresh water aquifer in the vicinity of the project area and to the salt mining operations due to movement of the saline groundwater interface would be less than significant.

6.2.7 POTENTIAL FOR LONG-TERM DRAWDOWN OF GROUNDWATER

The amount of groundwater in storage underlying the Bristol, Fenner and Cadiz valleys is estimated to be 16.9 MAF (CDWR 1975). The aquifer system underlying these valleys encompasses an area of approximately 1,860 square miles (CDWR 1975). The depth to groundwater in these groundwater basins is estimated to range from less than 10 feet to over 400 feet below ground surface. The depth to groundwater in the Fenner Gap area is about 274 feet below ground surface (Metropolitan 1999b).

During the Operational phase, groundwater levels would rise in the area surrounding the spreading basins in response to storage of Colorado River water, and fall in the area surrounding the project wellfield in response to extraction of stored Colorado River water and indigenous groundwater. The localized area with the greatest potential for long-term drawdown of groundwater levels directly underlies the project wellfield. To a lesser extent, drawdown of groundwater would occur in the area immediately surrounding the project wellfield.

As specified in the Management Plan (Section 3.6), static groundwater levels would be monitored regularly beginning in the Pre-Operational phase, throughout the Operational phase and through the Post-Operational phase. Groundwater levels would be monitored continuously using downhole pressure transducers in designated wells described in the Management Plan. The project observation well network could be supplemented with a network of microgravity stations located in the immediate project area. Supplemental data gathered with the microgravity stations could be used in addition to water levels measured in observation wells.

To prevent significant adverse impacts to long-term groundwater levels throughout the aquifer system due to project operations, corrective measures would be implemented as required in the Management Plan (Section 3.7). Corrective measures entail modification of project operations such as reduced groundwater extraction. Implementation of the Closure Plan would require that Pre-Operational average static groundwater levels would not be depressed by more than 100 feet in the area underlying the project wellfield at the conclusion of the Operational phase. The Closure Plan would be implemented during the Operational phase and would remain in effect through out the entire Post-Operational phase, which would be a minimum of 10 years, and would continue as long as deemed necessary to prevent potential adverse impacts. All provisions of the Management Plan would remain in effect and run concurrently with the term of the Post-Operational phase. In addition, all water use associated with the Cadiz Valley Agricultural Development would be governed by the provisions of the Management Plan including the provisions of the Closure Plan.

As a result of the above provisions the potential adverse impacts due to the potential for long-term drawdown of groundwater would be less than significant.

6.3 POTENTIAL IMPACTS TO BRISTOL AND CADIZ DRY LAKES

6.3.1 POTENTIAL IMPACTS TO BRINE RESOURCES AT BRISTOL AND CADIZ DRY LAKES

The potential impacts related to the brine resources of Bristol and Cadiz dry lakes can be divided into two areas: 1) dilution of brine resources, and 2) migration of stored Colorado River water constituents. These potential impacts are discussed below.

6.3.1.1 Potential Dilution of Brine and Effects on Salt Mining Operations

During storage of Colorado River water, the lateral extent of mounding would not be expected to reach either Bristol Dry Lake or Cadiz Dry Lake. However, if Colorado River water were to reach these dry lakes, it would migrate upward to the dry lake surface and evaporate. The evaporation potential of the dry lakes is adequate to accommodate any such increased recharge. Therefore, dilution of brines would not occur, and the salt mining operations would not be affected, and this impact would be less than significant.

Potential migration of stored Colorado River water during long storage periods would be managed by using the project wellfield for periodic pumping and re-spreading of the extracted groundwater to avoid loss of stored Colorado River water. This project operational criterion would minimize migration of stored water toward Bristol or Cadiz dry lakes.

In addition, TDS levels would be regularly measured at the cluster wells between the project wellfield and the margins of the dry lakes. If TDS levels changed in excess of 25 percent of background levels, or water or brine levels changed by one foot in the cluster wells at the margins of the dry lakes, these changes would be evaluated in accordance with the provisions of the Management Plan. Corrective measures that would be implemented, as appropriate, would include modification of project storage and extraction operations to re-establish the natural hydraulic gradient and background TDS concentrations at the margins of Bristol and Cadiz dry lakes. Accordingly, the potential adverse impacts to the salt mining operations would be less than significant.

6.3.1.2 Potential Migration of Stored Water Constituents into the Brine Resources

No Colorado River water is anticipated to migrate to Bristol or Cadiz dry lakes during the term of the Cadiz Project. However, should any Colorado River water migrate to the dry lakes and evaporate, it would contribute sodium and calcium to these dry lakes for the production of calcium chloride and sodium chloride because Colorado River water contains more sodium and calcium than the indigenous groundwater. The availability of chloride in the brine underlying the dry lakes could facilitate production of these compounds and be beneficial to salt mining operations on the Bristol and Cadiz dry lakes. Accordingly, adverse impacts would be less than significant.

Any Colorado River water that migrates to the dry lakes would also contribute a small amount of perchlorate to Bristol and Cadiz dry lakes. As stated above, perchlorate has been detected as a constituent in Colorado River water at concentrations ranging from non-detectable to as high a 9 μg/L. The current provisional State of California Department of Health Services maximum contaminant level for perchlorate is 18 μg/L. Perchlorate is a salt and would become a very small component of the TDS constituents comprising the brines at Bristol and Cadiz dry lakes. It is anticipated that most of the Colorado River water introduced into the groundwater basin would be extracted by the Cadiz Project wellfield. As a result, adverse impacts would be less than significant.

6.3.2 POTENTIAL IMPACTS TO AIR QUALITY DUE TO DUST MOBILIZATION AT BRISTOL AND CADIZ DRY LAKES

It is currently believed that the groundwater (brine water) beneath the lakebeds is sufficiently near the ground surface to moisten the surface soils through the capillary rise of moisture off of the water table. It is also believed that brine beneath the lakebeds is hydraulically connected to the freshwater aquifer outside the dry lakes. If so, excessive lowering of the groundwater surface beneath the dry lakes could lower brine levels to a level where capillary rise is reduced. Potential for increased mobilization of dry lake dust due to project operations would occur if: 1) the surface soils on Bristol and Cadiz dry lakes were to dry out; and 2) the drying out of surface soils, (attributable to project operations) would result in an increased potential for wind-blown dry lake dust.

To ensure that project operations would not result in water level changes beneath Bristol and Cadiz dry lakes that would cause an increase in dust mobilization, the Management Plan requires the TRT to monitor and analyze potential changes to air quality (airborne dust), groundwater levels beneath the dry lakes, soil moisture and evapotranspiration (ET) at the dry lake surfaces, and wind speed and direction at the dry lakes and in the region. Correlation of groundwater level information, soil moisture, ET, airborne particulate measurements, and wind speed would allow judgements to be made as to whether the Cadiz Project was contributing to any increase in the frequency or severity of dust storms on the dry lakes. Because the Management Plan would use a conservative action criterion for groundwater levels beneath the dry lakes, any adverse changes would be detected early, and modifications to the project operations identified through the Management Plan decision-making process would be implemented to promptly reverse any condition before it would become a significant effect.

Further, monitoring of regional wind speed and direction as specified in the Management Plan would provide information necessary to determine whether there are sufficient meteorological occurrences to transport any such project-mobilized dust into a Class I area designated by the Clean Air Act. Currently, the only Class I area in the region is Joshua Tree National Park. Should such potential exist, monitoring at the boundary of the Class I area would be implemented and project operations would be modified, if necessary, to avoid adverse visibility impacts through the decision-making process outlined in the Management Plan.

Corrective measures that would be implemented, as appropriate, would include modification of project storage and extraction operations to re-establish the natural hydraulic gradient. Modifications to project operations would include one or more of the following: (a) reduction in pumping from project wells, (b) revision of pumping locations within the project wellfield, (c) stoppage of groundwater extraction for a duration necessary to correct the predicted impact, or (d) delivery of Colorado River water, if available, to the project spreading basins.

Accordingly, the potential adverse impacts to air quality due to the mobilization of dust on Bristol and Cadiz dry lakes would be less than significant.

6.4 POTENTIAL IMPACTS TO WATER QUALITY IN THE COLORADO RIVER AQUEDUCT DUE TO INTRODUCTION OF INDIGENOUS GROUND-WATER

Potential changes to water quality in the CRA resulting from introduction of indigenous groundwater from the project area include: (1) reduction of TDS levels; (2) reduction of perchlorate concentration; (3) increase in bromide concentration; (4) increase in arsenic concentration; and (5) and increase in nitrate concentration. Introduction of indigenous groundwater can provide water supply reliability and water quality benefits with regards to certain constituents. Although introduction of indigenous groundwater into the CRA would raise concentrations of some undesirable constituents, these constituent levels in the CRA would remain within standards for drinking water established by the California Department of Health Services. Accordingly, adverse impacts to water quality in the CRA would be less than significant.

6.5 POTENTIAL IMPACTS TO FENNER GAP MICROCLIMATE

Average annual evaporation pan measurements in the Amboy area, located approximately 15 miles west of the Cadiz Project area, average 158 inches per year. Actual evaporation rates from a larger surface water body, such as the project spreading basins, would be approximately 70 percent of the pan evaporation rate (Chow 1964).

Because the elevation of Fenner Gap is approximately 300 feet higher than that of Amboy, the annual evaporation is expected to be slightly lower. This has been verified with an evaporation pan located immediately adjacent to the pilot spreading basins in Fenner Gap. However, the record for this installation is relatively short-term, and the Amboy pan data have been employed here as a conservative estimate (Figure 2-7).

Based on the corrected surface water evaporation values obtained from the Amboy evaporation pan, the amount of water expected to evaporate from the project spreading basins ranges from approximately 600 to 1,000 acre-feet per year over the 50-year term of the project. Evaporation would occur only during spreading operations. The maximum projected evaporation estimate is approximately three percent of the total volume of Colorado River water to be stored in the project area. For comparison, Lake Havasu, located on the Colorado River east of the project area, loses approximately 133,000 acre-feet of water each year to evaporation (CDWR, 1979). This corresponds to a loss of approximately 22 percent of its total storage capacity every year.

The effect of evaporation from the project spreading basins on the microclimate of Fenner Gap is expected to be minimal. It is anticipated that the majority of spreading would occur during the first 15 years out of the 50-year term of the Operational phase. In addition, minor spreading may be conducted during the storage periods to maintain the project wellfield and meet the Management Plan objectives. As a result, the amount of time that water would be susceptible to evaporation would be minor in comparison to the life of the project. Therefore, the existing natural long-term climatic conditions in Fenner Gap would not be significantly affected by the project.

6.6 POTENTIAL IMPACTS TO THE DESERT ENVIRONMENT DUE TO IMPLEMENTATION OF THE MANAGEMENT PLAN

The Management Plan would require the installation, inspection and maintenance of monitoring facilities to provide for collection of data. These facilities are detailed in Table 3-1 and Figures 3-4 and 3-5 of the Management Plan (Section 3.0) which include more specific information such as frequency of monitoring and conceptual location.

These monitoring facilities are generally sited in three areas: 1) the project area aquifer, 2) on the lakebeds or the margins of Bristol and Cadiz dry lakes, and 3) the Mojave National Preserve and surrounding areas. Facilities in the project area aquifer would include approximately 20 survey benchmarks; three cluster wells, each consisting of three observation wells; use and potential modification of 14 existing observation wells; construction of one new observation well; and construction of one 10-meter-tall meteorological tower. Facilities on the lakebeds or near the margins of Bristol and Cadiz dry lakes would include six new cluster wells, each consisting of three observation wells; two evapotranspiration monitoring stations; two staff gages; and four air quality monitoring stations. Facilities between the project area and the Mojave National Preserve would include four cluster wells, each consisting of two or three wells; and two soil moisture sensors. One new weather station would be located in the Mojave National Preserve. Additionally, one meterological tower would be installed between Bristol Dry Lake and Joshua Tree National Park.

Additionally, an inventory of springs in the Preserve and surrounding area would be prepared. Approximately eight of these springs would be selected for regular monitoring. If necessary, two stream gages could be constructed in the Mojave National Preserve and surrounding area. If necessary, certain additional monitoring facilities could be constructed in the project area aquifer and include an extensometer well and 10 microgravity stations.

The Management Plan has identified conceptual locations for the monitoring facilities. During the implementation of the Management Plan, additional technical information would be developed to select specific locations for all monitoring facilities. Impacts associated with the monitoring program would be related to the drilling of new monitoring wells at specific locations, modification of existing wells for monitoring purposes, placement of other types of monitoring equipment within the potentially affected region, and inspecting these facilities to collect data and provide maintenance. There is also the potential for the development of new access or power distribution facilities to support the monitoring facilities. However, it is the intent of the Management Plan to site monitoring facilities such that existing access and power facilities would be used to the extent practicable. Additionally, monitoring facilities would be sited to avoid or minimize the potential environmental impacts discussed below.

The monitoring program could adversely affect biological resources, cultural and paleontological resources, and aesthetic, wilderness and recreational values. Potential direct effects would be caused by construction of facilities, modification of existing facilities, inspection of facilities to collect data, and provision of maintenance. Indirect effects would be caused by increased public use of remote areas of the desert through new or improved access.

Wildlife habitat would be affected and lost to construction of facilities. As discussed in the Draft EIR/EIS, the predominant habitat type in the eastern Mojave Desert is creosote scrub, and it is most likely that this habitat type would be affected. Additionally, the threatened desert tortoise could be affected by such habitat losses and by inspection and maintenance of monitoring facilities. The installation of any new, above-grade power distribution facilities and meterological towers could indirectly affect the tortoise by providing perching and nesting opportunities for predatory ravens.

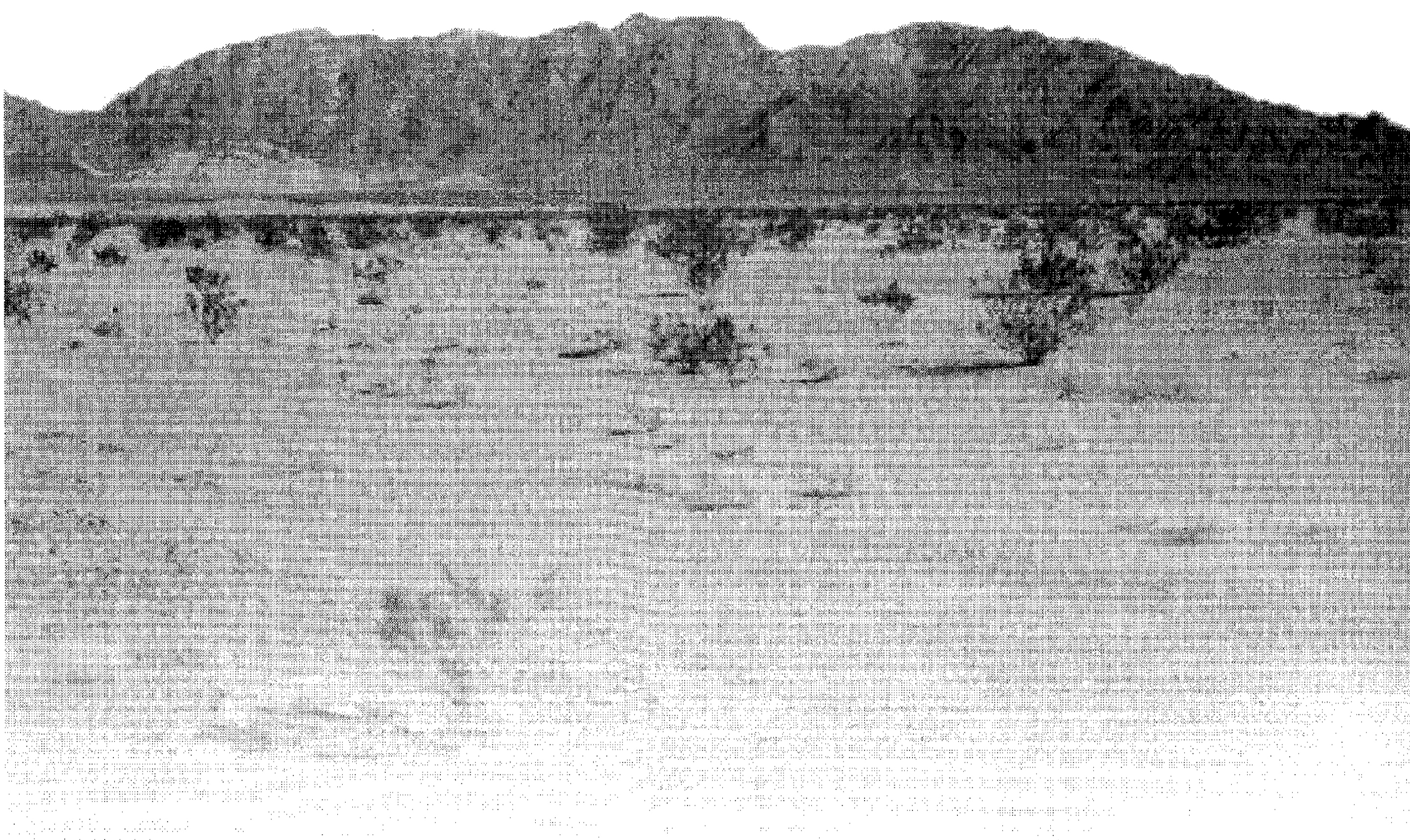
Cultural resources, such as historic and pre-historic remnants of past human use, and paleontological resources (fossil localities) could be affected directly if they were not avoided by ground disturbance necessary for construction or modification of facilities, or indirectly if improved or new access increases the potential for disturbance.

Any new access or power distribution facilities would have long-term effects on aesthetic values in the desert, particularly if they occur in previously undisturbed portions of the desert. The monitoring facilities are quite small and would not be noticeable from a distance. Visual impacts to the landscape associated with construction would be somewhat larger, but would blend back into the desert landscape over time. Wilderness and recreational values could be adversely affected by such aesthetic impacts if they occurred in proximity to wilderness areas or other areas used for recreational purposes.

Prior to construction of monitoring and appurtenant facilities necessary to implement the Management Plan, Metropolitan and BLM would prepare appropriate environmental documentation and would coordinate with agencies having jurisdiction over resources that could be affected by implementation of the Management Plan.

SECTION 7.0

Cumulative Effects to Water Resources



SECTION 7.0

SECTION 7.0
CUMULATIVE EFFECTS TO WATER RESOURCES

This section summarizes potential cumulative project-related environmental impacts to water resources resulting from the Cadiz Project when combined with other water uses in the vicinity of the Cadiz Project area and located within the Bristol, Cadiz, Fenner, and Orange Blossom Wash watersheds. This discussion supplements Section 7.5.5 of the Draft EIR/EIS, which addresses cumulative impacts to water resources. This cumulative impact analysis evaluates past, present, and reasonably foreseeable water uses in the vicinity of the project area consisting of miscellaneous uses within the Mojave National Preserve (Preserve) and on federal lands administered by the BLM, the Cadiz Valley Agricultural Development, domestic wells, stock wells, wells owned BNSF and El Paso Natural Gas, and salt-mining operations on Bristol and Cadiz dry lakes.

7.1 PAST, PRESENT, AND REASONABLY FORESEEABLE WATER USES WITHIN THE BRISTOL, CADIZ, FENNER AND ORANGE BLOSSOM WASH WATERSHEDS

7.1.1 MOJAVE NATIONAL PRESERVE

The Mojave National Preserve is located approximately 15 miles north of the Cadiz Project area and includes portions of the Fenner Valley and Orange Blossom Wash watersheds, which are tributary to the project area. Groundwater underlying the Preserve flows generally southward toward the Cadiz Project area. Small-yield wells produce groundwater for domestic use, camping, and stock watering. Use by wildlife is generally limited to naturally occurring springs and man-made guzzlers. Most springs within the preserve are small and flow less than 5 gallons per minute (Freiwald 1984 as cited in NPS 1999). An inventory of 28 known springs within the Fenner and Orange Blossom Wash watersheds would be prepared in cooperation with the agencies within the U.S. Department of the Interior.

Detailed information regarding water use within the Preserve is limited, and the NPS has identified future investigation and documentation of this resource as a high priority (NPS 1999). The only quantitative water use information available within the preserve is for the fire station, Visitor Information Center (kiosk) and campground located at Hole-in-the-Wall, within the Fenner Valley watershed (Chris Stubbs, NPS, personal communication, June 2000). Water use at these facilities reaches a peak of approximately 1,700 gallons/day in the summer when demand for fire suppression is highest, and drops to approximately 500 to 800 gallons/day in the winter (when demand is highest from campers) (David Moore, NPS, personal communication, June 2000). Total water use at these facilities is estimated to average no more than 1.4 acre-feet/year. This use is not expected to appreciably expand in the foreseeable future (Chris Stubbs, NPS, personal communication, June 2000).

7.1.2 FEDERAL LANDS ADMINISTERED BY BLM

The BLM administers federal lands outside of the Preserve within the Bristol, Cadiz, Fenner and Orange Blossom Wash watersheds. Water uses on these lands are similar to those in the Preserve, and include stock watering, mining, and use by wildlife. Quantitative information on water use is not available.

7.1.3 WATER USES ON PRIVATE LAND

Water uses on private land within the Bristol, Cadiz, Fenner and Orange Blossom Wash watersheds include domestic use, stock watering, agriculture, mining, grazing, and use by wildlife. In the vicinity of the project area, groundwater is produced from wells owned by the BNSF, one well owned by El Paso Natural Gas (formerly owned by All American Pipeline LLP), the Cadiz Valley Agricultural Development, domestic residences, and the salt mining operations on Bristol and Cadiz dry lakes.

It is estimated that fewer than 20 individuals live in the community of Chambless, located approximately 5 miles north of the proposed project wellfield, and fewer than 100 individuals are estimated to live within the watersheds tributary to the project area. Domestic water use in the region is not expected to increase appreciably in the foreseeable future.

7.1.4 CADIZ AGRICULTURAL DEVELOPMENT

Cadiz owns more than 27,000 acres in the vicinity of the project area as shown in Figure 2-1. Approximately 1,600 acres of this land have been developed for vineyards, citrus orchards, and various types of row crops. Seven groundwater production wells were installed between 1984 and 1994 to provide irrigation for the agricultural operation using water-conserving drip and micro-spray techniques. Current groundwater use for irrigation averages between approximately 5,000 and 6,000 acre-feet/year.

In 1993, San Bernardino County certified a Final Environmental Impact Report (FEIR) (SCH#89020203) and granted various land-use approvals for expansion of operations in the Cadiz Valley Agricultural Development up to 9,600 acres. The FEIR anticipated the withdrawal of up to 30,000 acre-feet/year for agricultural irrigation at build-out.

As a component of the FEIR, the County identified specific groundwater monitoring activities to be undertaken by Cadiz. To comply with these monitoring requirements, the Cadiz Valley Agricultural Development Ground Water Monitoring Plan (GWMP) was developed in cooperation with San Bernardino County to monitor potential environmental impacts that could result from the agricultural operations. Expansion of the agricultural operation to 9,600 acres could occur without any further discretionary approvals subject to the provisions of the GWMP.

7.1.5 SALT MINING OPERATIONS ON BRISTOL AND CADIZ DRY LAKES

As described in Section 2.6, salt mining operations on Bristol and Cadiz dry lakes produce both calcium chloride and sodium chloride from highly saline brines. Mining claims on Bristol Dry Lake date from 1908, and gypsum deposits were worked until approximately 1924-25. The saline brine, produced from both wells and trenches, is pumped into ponds for concentration by evaporation. When the brine solution reaches marketable densities, it is pumped from the evaporation ponds and shipped or converted into a dry product at flaking facilities. The area of surface disturbance by these mining facilities is typically a small fraction (less than 1/10th) of the area under reclamation plan approval. The existing operations are generally low intensity (i.e. commonly 5-10 employees) for operations spread over hundreds of acres.

Mining is conducted on patented lands and on unpatented claims and leases on federal land administered by the BLM.

The following mining operations currently exist in the area:

- Tetra Technologies, Inc. is authorized to mine 960 acres on Bristol Dry Lake for the production of calcium chloride and sodium chloride.

- National Chloride Company of America is authorized to mine 162 acres on Bristol Dry Lake for the production of liquid calcium chloride and sodium chloride.

- Lee Chemical, Inc. is authorized to mine 685 acres on Cadiz Dry Lake for the production of liquid calcium chloride.

The locations of these operations are shown in Figures 5.9-1 through 5.9-4 in the Draft EIR/EIS. The Hills Brothers operation shown in these figures is a flaking plant, which processes brine produced by the above-described mining operations.

The amount of brine produced by these mining companies is proprietary information, and precise estimates are unavailable. However, none of the mining operations is expected to expand substantially in the foreseeable future (Ken Downing and Kathleen Cox, BLM; and Rich Touslee, San Bernardino County, personal communication, June 2000).

7.2 CUMULATIVE IMPACTS TO WATER RESOURCES

Cumulative impacts refer to two or more individual impacts that, when considered together, are substantial or that compound or increase other environmental impacts. The cumulative impact of a project or action would be the change in the environment that results from the incremental impact of the proposed project or action when added to other past, present, or reasonably foreseeable future projects or actions. Cumulative impacts could result from individually minor but collectively significant projects taking place over a period of time (CEQA Guidelines Section 15355; 40 C.F.R. Section 1508.7).

The Rail Cycle Project, proposed by Waste Management, Inc. for a Class III solid waste landfill, does not appear to be reasonably foreseeable at this time. In 1996, the voters of San Bernardino failed to approve a tax proposed by the San Bernardino County Board of Supervisors as a condition of the approval for the Rail Cycle Project. In August 2000 the California Court of Appeal (4^{th} District) ruled the Environmental Impact Report prepared in connection with the Rail Cycle Project was invalid. As a result, Rail Cycle Project environmental and land use approvals are revoked. Additionally, the Rail Cycle Project continues to be the subject of criminal litigation.

Accordingly, there are no reasonably foreseeable future projects contemplated in the regional watersheds tributary to the Cadiz Project area.

All of the groundwater uses discussed above combined, with the exception of the Cadiz Valley Agricultural Development, are very small in relation to the estimated 3.7 to 6.7 million acre-feet of indigenous groundwater with less than 1,000 mg/L TDS in storage in the aquifer system underlying the area of the proposed project wellfield (Metropolitan 1999b). Accordingly, these combined uses do not result in significant adverse impacts to groundwater supplies.

The Cadiz Project would not result in significant adverse impacts to water resources because all project operations would be subject to the provisions of the Management Plan, presented in Section 3.0. The Management Plan was prepared as a result of cooperative efforts by Metropolitan, BLM, NPS, USGS, the County of San Bernardino, and Cadiz Inc. A fundamental objective of the Management Plan would be to provide "early warning" of potential adverse impacts to critical environmental resources in and surrounding the project area that could result from project operations. With such early warning, adverse impacts would be prevented by implementation of suitable corrective actions.

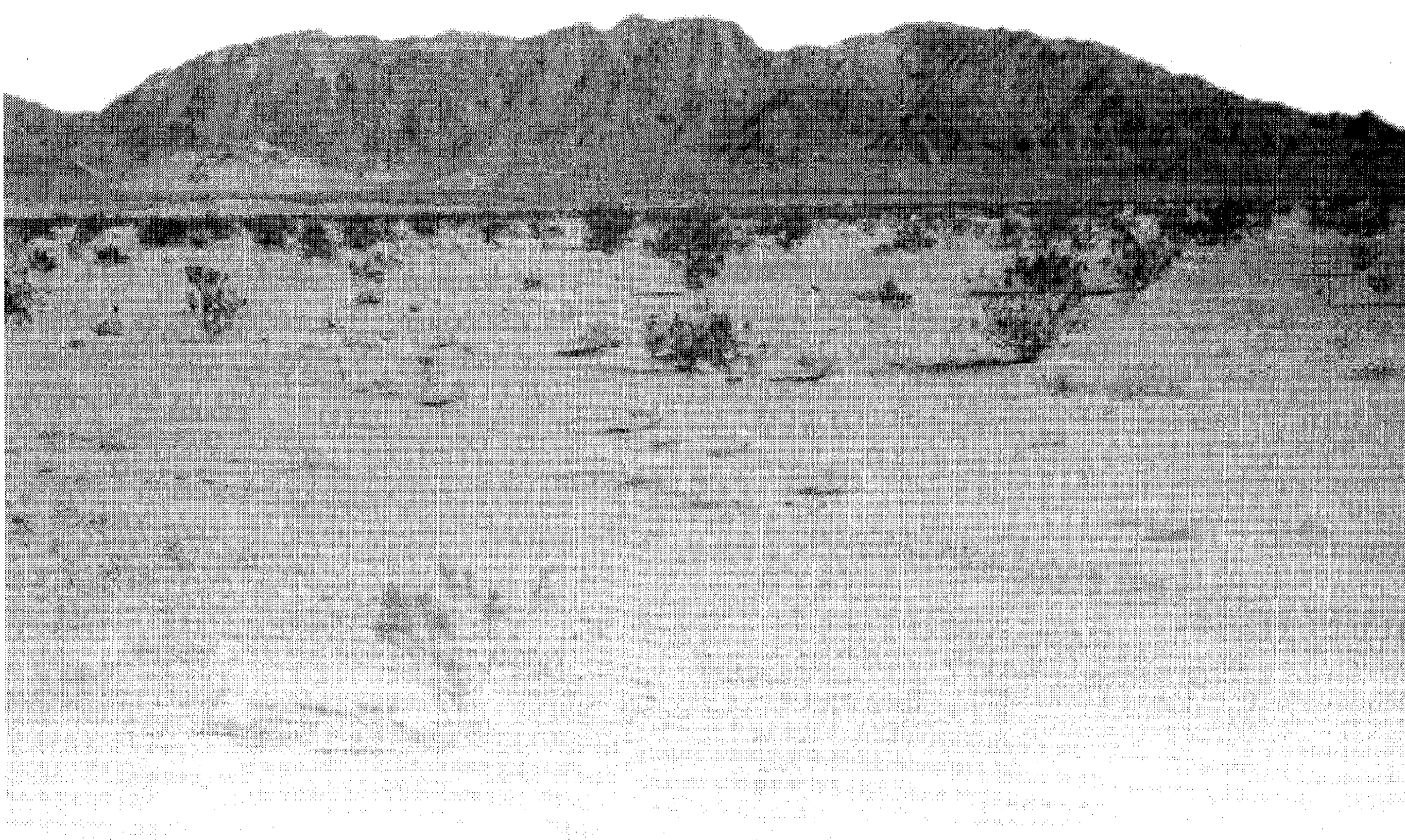
With approval and implementation of the Cadiz Project, all future groundwater use for irrigation in the project area including any existing or future expansion of the Cadiz Valley Agricultural Development would also be subject to the provisions of the Management Plan. As presented in Section 3.0, the Management Plan provides for a comprehensive program of monitoring designed to ensure that project operations and future irrigation under the Cadiz Valley Agricultural Development would be conducted without adverse impact to any critical environmental resources in and surrounding the project area. Thus, with implementation of the Cadiz Project and Management Plan, any potential adverse impact of the Cadiz Valley Agricultural Development would be fully mitigated to below a level of significance.

The Management Plan also contains provisions designed to ensure that the other water uses discussed above would not be impacted by the addition of the Cadiz Project. With respect to water uses within the preserve, the Management Plan outlines specific provisions to prevent any impacts to groundwater levels or springs as a result of project operations. Likewise, the Management Plan outlines specific provisions to prevent any impacts to springs located within designated BLM Wilderness areas and to Bonanza Spring, located on BLM administered federal land approximately 12 miles north of the project area. The Management Plan also outlines specific provisions to prevent and/or mitigate adverse impacts to potable water wells owned by neighboring landowners in proximity to the project area. The Management Plan also provides for a comprehensive program of monitoring designed to ensure that project operations would not adversely impact the brine resources on Bristol and Cadiz dry lakes.

Because the combined impact of all water uses in the area, except the Cadiz Project and the Cadiz Valley Agricultural Development, would not have potentially significant adverse impacts on groundwater supplies and because the Management Plan would ensure that the Cadiz Project and the Cadiz Valley Agricultural Development would not have any significant adverse impacts on water resources, the cumulative impact of the Cadiz Project and all other past, present and reasonably foreseeable future water uses in the area is determined to be less than significant.

SECTION 8.0

Indices for the Draft EIR/EIS and the Supplement



SECTION 8.0
INDICES FOR THE DRAFT EIR/EIS AND THE SUPPLEMENT

This section provides detailed indices by topic for the November 1999 Draft EIR/EIS and this Supplement to the Draft EIR/EIS.

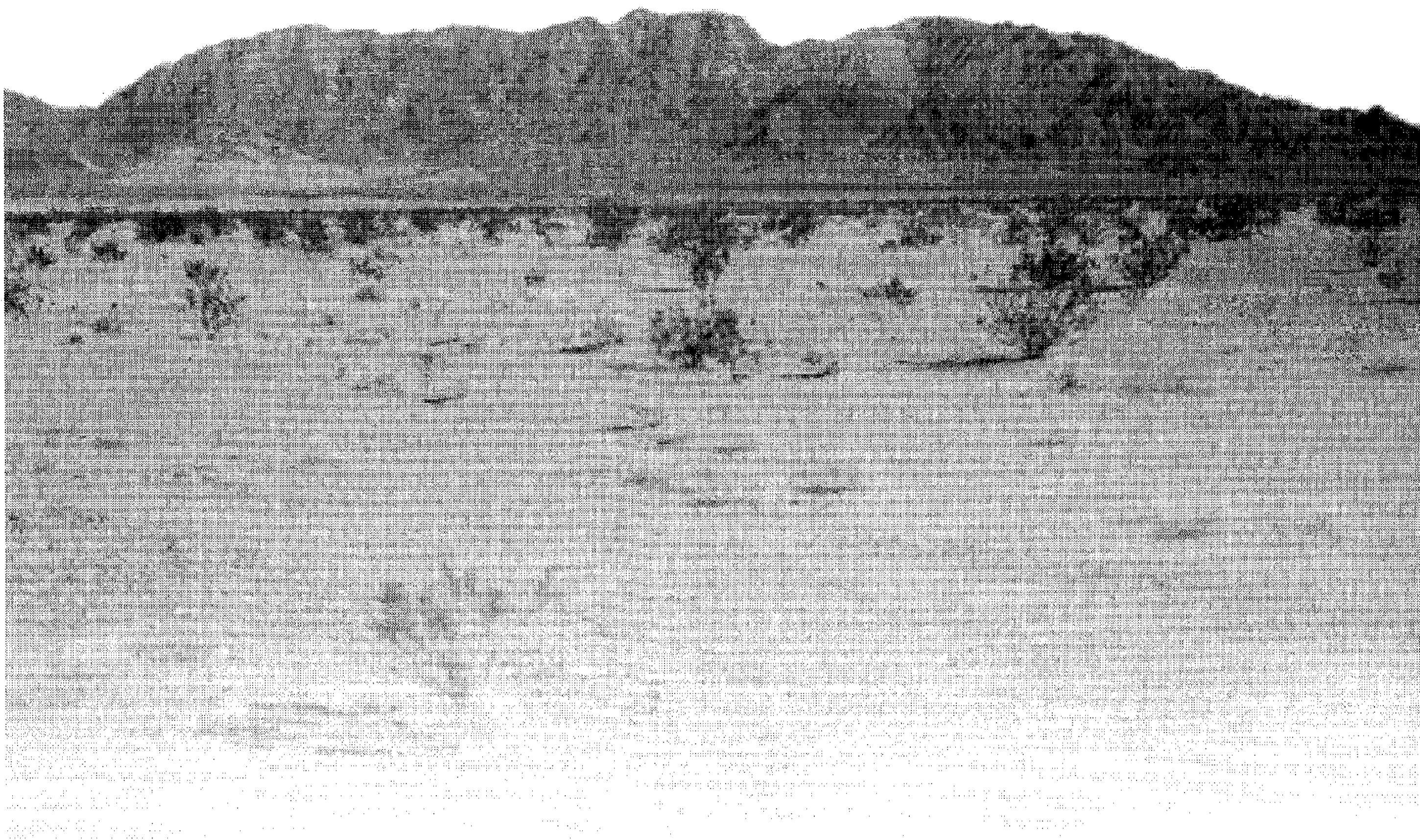
8.1 INDEX FOR THE DRAFT EIR/EIS

The index for the Draft EIR/EIS is provided below, followed by the index for the Supplement to the Draft EIR/EIS.

8.2 INDEX FOR THE SUPPLEMENT TO THE DRAFT EIR/EIS

The index for the Supplement to the Draft EIR/EIS is provided below.

SECTION 9.0
List of Preparers



SECTION 9.0

SECTION 9.0
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SECTION 10.0
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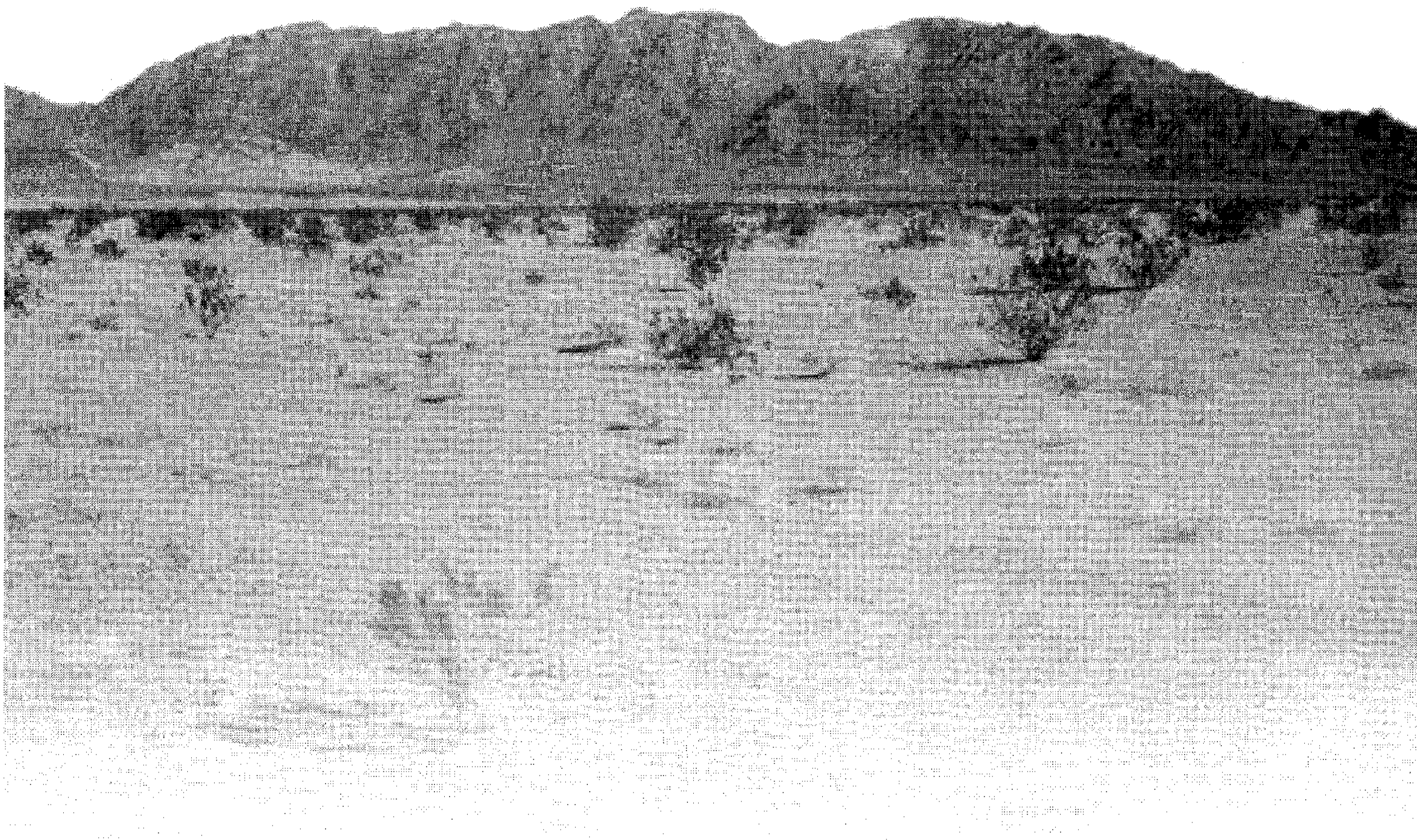

SECTION 10.0

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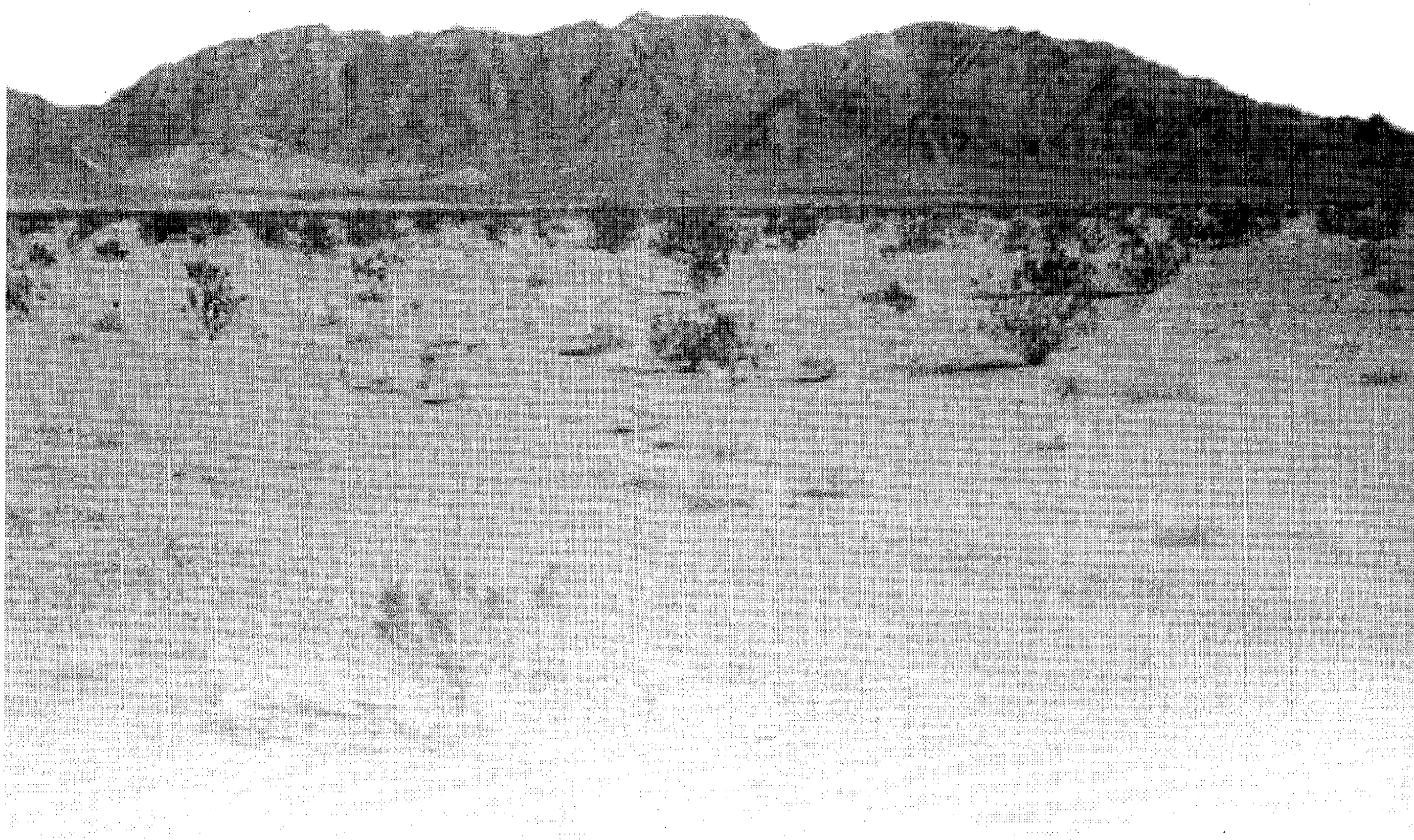
SECTION 11.0
Appendices



APPENDIX A

ASTM D5092-90, Standard Practice for Design and Installation of Groundwater Observation Wells in Aquifers

ASTM STANDARDS ON GROUND WATER AND VADOSE ZONE INVESTIGATIONS

Sponsored by ASTM Committee D-18
on Soil and Rock

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Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers[1]

This standard is issued under the fixed designation D 5092; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This practice for the design and installation of ground water monitoring wells in aquifers will promote (*1*) durable and reliable construction, (*2*) extraction of representative ground water quality samples, and (*3*) efficient and site hydrogeological characterizations. The guidelines established herein are affected by governmental regulations and by site specific geological, hydrogeological, climatological, topographical, and subsurface chemistry conditions. To meet these geoenvironmental challenges, this guidance promotes the development of a conceptual hydrogeologic model prior to monitoring well design and installation.

1. Scope

1.1 This practice considers the selection and characterization (that is, defining soil, rock types, and hydraulic gradients) of the target monitoring zone as an integral component of monitoring well design and installation. Hence, the development of a conceptual hydrogeologic model for the intended monitoring zone(s) is recommended prior to the design and installation of a monitoring well.

1.2 These guidelines are based on recognized methods by which monitoring wells may be designed and installed for the purpose of detecting the presence or absence of a contaminant, and collecting representative ground water quality data. The design standards and installation procedures herein are applicable to both detection and assessment monitoring programs for facilities.

1.3 The recommended monitoring well design, as presented in this practice, is based on the assumption that the objective of the program is to obtain representative ground water information and water quality samples from aquifers. Monitoring wells constructed following this practice should produce relatively turbidity-free samples for granular aquifer materials ranging from gravels to silty sand and sufficiently permeable consolidated and fractured strata. Strata having grain sizes smaller than the recommended design for the smallest diameter filter pack materials should be monitored by alternative monitoring well designs which are not addressed in this practice.

1.4 The values stated in inch-pound units are to be regarded as standard. The values in parentheses are for information only.

1.5 *This standard does not purport to address the safety problems associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

C 150 Specification for Portland Cement[2]
C 294 Descriptive Nomenclature of Constituents of Natural Mineral Aggregates[3]
D 653 Terminology Relating to Soil, Rock, and Contained Fluids[4]
D 1452 Practice for Soil Investigation and Sampling by Auger Borings[4]
D 1586 Method for Penetration Test and Split-Barrel Sampling of Soils[4]
D 1587 Practice for Thin-Walled Tube Sampling of Soils[4]
D 2113 Practice for Diamond Core Drilling for Site Investigation[4]
D 2487 Test Method for Classification of Soils for Engineering Purposes[4]
D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)[4]
D 3282 Practice for Classification of Soils and Soil Aggregate Mixtures for Highway Construction Purposes[4]
D 3550 Practice for Ring Lined Barrel Sampling of Soils[4]
D 4220 Practice for Preserving and Transporting Soil Samples[4]

3. Significance and Use

3.1 An adequately designed and installed ground water monitoring well system for aqueousphase liquids provides essential information for decisions pertaining to one or more of the following subjects:

3.1.1 Aquifer and aquitard properties, both geologic and hydraulic;

[1] This practice is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21.05 on Design and Installation of Ground-Water Monitoring Wells.

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[2] *Annual Book of ASTM Standards*, Vol 04.01.
[3] *Annual Book of ASTM Standards*, Vol 04.02.
[4] *Annual Book of ASTM Standards*, Vol 04.08.

3.1.2 Potentiometric surface of a particular hydrologic unit(s);

3.1.3 Water quality with respect to various indicator parameters;

3.1.4 Migration characteristics of a contaminant release;

3.1.5 Additional installations or decommissioning of installations, or both, no longer needed.

4. Terminology

4.1 *Definitions:*

4.1.1 *annular space; annulus*—the space between two concentric tubes or casings, or between the casing and the borehole wall. This would include the space(s) between multiple strings of tubing/casings in a borehole installed either concentrically or multi-cased adjacent to each other.

4.1.2 *assessment monitoring*—an investigative monitoring program that is initiated after the presence of a contaminant in ground water has been detected. The objective of this program is to determine the concentration of constituents that have contaminated the ground water and to quantify the rate and extent of migration of these constituents.

4.1.3 *ASTM cement types*—Portland cements meeting the requirements of Specifications C 150. Cement types have slightly different formulations that result in various characteristics which address different construction conditions and different physical and chemical environments. They are as follows:

4.1.3.1 *Type I (Portland)*—a general-purpose construction cement with no special properties.

4.1.3.2 *Type II (Portland)*—a construction cement that is moderately resistant to sulfates and generates a lower head of hydration at a slower rate than Type I.

4.1.3.3 *Type III (Portland; high early strength)*—a construction cement that produces a high early strength. This cement reduces the curing time required when used in cold environments, and produces a higher heat of hydration than Type I.

4.1.3.4 *Type IV (Portland)*—a construction cement that produces a low head of hydration (lower than Types I and II) and develops strength at a slower rate.

4.1.3.5 *Type V (Portland)*—a construction cement that is a high sulfate resistant formulation. Used when there is severe sulfate action from soils and ground water.

4.1.4 *bailer*—a hollow tubular receptacle used to facilitate withdrawal of fluid from a well or borehole.

4.1.5 *ballast*—materials used to provide stability to a buoyant object (such as casing within a borehole filled with water).

4.1.6 *blow-in*—the inflow of ground water and unconsolidated material into a borehole or casing caused by differential hydraulic heads; that is, caused by the presence of a greater hydraulic head outside of a borehole/casing than inside.

4.1.7 *borehole* a circular open or uncased subsurface hole created by drilling.

4.1.8 *borehole log*—the record of geologic units penetrated, drilling progress, depth, water level, sample recovery, volumes, and types of materials used, and other significant facts regarding the drilling of an exploratory borehole or well.

DISCUSSION—The definition of aquifer as currently included in Terminology D 653 varies from the definition as prescribed by US federal regulations. Since this federal definition is associated with the installation of many monitoring wells it is provided herein as a technical note:

aquifer—a geologic formation, group of formation, or part of a formation that is saturated, and is capable of providing a significant quantity of water.

4.1.9 *bridge*—an obstruction within the annulus which may prevent circulation or proper emplacement of annular materials.

4.1.10 *casing*—pipe, finished in sections with either threaded connections or bevelled edges to be field welded, which is installed temporarily or permanently to counteract caving, to advance the borehole, or to isolate the zone being monitored, or combination thereof.

4.1.11 *casing, protective*—a section of larger diameter pipe that is emplaced over the upper end of a smaller diameter monitoring well riser or casing to provide structural protection to the well and restrict unauthorized access into the well.

4.1.12 *casing, surface*—pipe used to stabilize a borehole near the surface during the drilling of a borehole that may be left in place or removed once drilling is completed.

4.1.13 *caving; sloughing*—the inflow of unconsolidated material into a borehole which occurs when the borehole walls lose their cohesive strength.

4.1.14 *cement; Portland cement*—commonly known as Portland cement. A mixture that consists of a calcareous, argillaceous, or other silica-, alumina-, and iron-oxide-bearing materials that is manufactured and formulated to produce various types which are defined in Specification C 150. Portland cement is also considered a hydraulic cement because it must be mixed with water to form a cement-water paste that has the ability to harden and develop strength even if cured under water (see *ASTM cement types*).

4.1.15 *centralizer*—a device that assists in the centering of a casing or riser within a borehole or another casing.

4.1.16 *circulation*—applies to the fluid rotary drilling method; drilling fluid movement from the mud pit, through the pump, hose and swivel, drill pipe, annular space in the hole and returning to the mud pit.

4.1.17 *conductance (specific)*—a measure of the ability of the water to conduct an electric current at 77°F (25°C). It is related to the total concentration of ionizable solids in the water. It is inversely proportional to electrical resistance.

4.1.18 *confining unit*—a term that is synonymous with "aquiclude," "aquitard," and "aquifuge;" defined as a body of relatively low permeable material stratigraphically adjacent to one or more aquifers.

4.1.19 *contaminant*—an undesirable substance not normally present in water or soil.

4.1.20 *detection monitoring*—a program of monitoring for the express purpose of determining whether or not there has been a contaminant release to ground water.

4.1.21 *drill cuttings*—fragments or particles of soil or rock, with or without free water, created by the drilling process.

4.1.22 *drilling fluid*—a fluid (liquid or gas) that may be used in drilling operations to remove cuttings from the borehole, to clean and cool the drill bit, and to maintain the integrity of the borehole during drilling.

4.1.23 *d-10*—the diameter of a soil particle (preferably in millimetres) at which 10 % by weight (dry) of the particles of a particular sample are finer. Synonymous with the effective size or effective grain size.

4.1.24 *d-60*—the diameter of a soil particle (preferably in millimetres) at which 60 % by weight (dry) of the particles of a particular sample are finer.

4.1.25 *flow path*—represents the area between two flow lines along which ground water can flow.

4.1.26 *flush joint or flush coupled*—casing or riser with ends threaded such that a consistent inside and outside diameter is maintained across the threaded joints or couplings.

4.1.27 *gravel pack*—common nomenclature for the terminology, primary filter of a well (see *primary filter pack*).

4.1.28 *grout (monitoring wells)*—a low permeability material placed in the annulus between the well casing or riser pipe and the borehole wall (that is, in a single-cased monitoring well), or between the riser and casing (that is, in a multi-cased monitoring well), to maintain the alignment of the casing and riser and to prevent movement of ground water or surface water within the annular space.

4.1.29 *grout shoe*—a *plug* fabricated of relatively inert materials that is positioned within the lowermost section of a permanent casing and fitted with a passageway, often with a flow check device, through which grout is injected under pressure to fill the annular space. After the grout has set, the grout shoe is usually drilled out.

4.1.30 *head (static)*—the height above a standard datum of the surface of a column of water (or other liquid) that can be supported by the static pressure at a given point. The static head is the sum of the elevation head and the pressure head.

4.1.31 *head (total)*—the sum of three components at a point: (*1*) elevation head, h_e, which is equal to the elevation of the point above a datum; (*2*) pressure head, hp, which is the height of a column of static water than can be supported by the static pressure at the point; and (*3*) velocity head, hv, which is the height the kinetic energy of the liquid is capable of lifting the liquid.

4.1.32 *hydrologic unit*—geologic strata that can be distinguished on the basis of capacity to yield and transmit fluids. Aquifers and confining units are types of hydrologic units. Boundaries of a hydrologic unit may not necessarily correspond either laterally or vertically to lithostratigraphic formations.

4.1.33 *jetting*—when applied as a drilling method, water is forced down through the drill rods or casings and out through the end aperture. The jetting water then transports the generated cuttings to the ground surface in the annulus of the drill rods or casing and the borehole. The term jetting may also refer to a development technique (see well screen jetting).

4.1.34 *loss of circulation*—the loss of drilling fluid into strata to the extent that circulation does not return to the surface.

4.1.35 *mud pit*—usually a shallow, rectangular, open, portable container with baffles into which drilling fluid and cuttings are discharged from a borehole and that serves as a reservoir and settling tank during recirculation of the drilling fluids. Under some circumstances, an excavated pit with a lining material may be used.

4.1.36 *multi-cased well*—a well constructed by using successively smaller diameter casings with depth.

4.1.37 *neat cement*—a mixture of Portland cement (Specification 150) and water.

4.1.38 *observation well*—typically, a small diameter well used to measure changes in hydraulic heads, usually in response to a nearby pumping well.

4.1.39 *oil air filter*—a filter or series of filters placed in the air flow line from an air compressor to reduce the oil content of the air.

4.1.40 *oil trap*—a device used to remove oil from the compressed air discharged from an air compressor.

4.1.41 *packer (monitoring wells)*—a transient or dedicated device placed in a well that isolates or seals a portion of the well, well annulus, or borehole at a specific level.

4.1.42 *potentiometric surface*—an imaginary surface representing the static head of ground water. The water table is a particular potentiometric surface.

DISCUSSION—Where the head varies with depth in the aquifer, a potentiometric surface is meaningful only if it describes the static head along a particular specified surface or stratum in that aquifer. More than one potentiometric surface is required to describe the distribution of head in this case.

4.1.43 *primary filter pack*—a clean silica sand or sand and gravel mixture of selected grain size and gradation that is installed in the annular space between the borehole wall and the well screen, extending an appropriate distance above the screen, for the purpose of retaining and stabilizing the particles from the adjacent strata. The term is used in place of *gravel pack*.

4.1.44 *PTFE tape*—joint sealing tape composed of polytetrafluoroethylene.

4.1.45 *riser*—the pipe extending from the well screen to or above the ground surface.

4.1.46 *secondary filter pack*—a clean, uniformly graded sand that is placed in the annulus between the primary filter pack and the over-lying seal, or between the seal and overlying grout backfill, or both, to prevent movement of seal or grout, or both, into the primary filter pack.

4.1.47 *sediment sump*—a blank extension beneath the well screen used to collect fine-grained material from the filter pack and adjacent strata. The term is synonymous with rat trap or tail pipe.

4.1.48 *shear strength (monitoring wells)*—a measure of the shear or gel properties of a drilling fluid or grout.

4.1.49 *single-cased well*—a monitoring well constructed with a riser but without an exterior casing.

4.1.50 *static water level*—the elevation of the top of a column of water in a monitoring well or piezometer that is not influenced by pumping or conditions related to well installation, hydrologic testing, or nearby pumpage.

4.1.51 *tamper*—a heavy cylindrical metal section of tubing that is operated on a wire rope or cable. It slips over the riser and fits inside the casing or borehole annulus. It is generally used to tamp annular sealants or filter pack materials into place and prevent bridging.

4.1.52 *target monitoring zone*—the ground water flow path from a particular area or facility in which monitoring wells will be screened. The target monitoring zone should be stratum (strata) in which there is a reasonable expectation that a vertically placed well will intercept migrating contaminants.

4.1.53 *test pit*—a shallow excavation made to characterize the subsurface.

4.1.54 *transmissivity*—the rate at which water of the prevailing kinematic viscosity is transmitted through a unit width of the aquifer under a unit hydraulic gradient.

DISCUSSION—It is equal to an integration of the hydraulic conductivities across the saturated part of the aquifer perpendicular to the flow paths.

4.1.55 *tremie pipe*—a pipe or tube that is used to transport filter pack materials and annular sealant materials from the ground surface into the borehole annulus or between casings and casings or riser pipe of a monitoring well.

4.1.56 *uniformly graded*—a quantitative definition of the particle size distribution of a soil which consists of a majority of particles being of the same approximate diameter. A granular material is considered uniformly graded when the uniformity coefficient is less than about five (Test Method D 2487). Comparable to the geologic term *well sorted*.

4.1.57 *vented cap*—a cap with a small hole that is installed on top of the riser.

4.1.58 *washout nozzle*—a tubular extension with a check valve utilized at the end of a string of casing through which water can be injected to displace drilling fluids and cuttings from the annular space of a borehole.

4.1.59 *weep hole*—a small diameter hole (usually ¼ in.) drilled into the protective casing above the ground surface that serves as a drain hole for water that may enter the protective casing annulus.

4.1.60 *well completion diagram*—a record that illustrates the details of a well installation.

4.1.61 *well screen*—a filtering device used to retain the primary or natural filter pack; usually a cylindrical pipe with openings of a uniform width, orientation, and spacing.

4.1.62 *well screen jetting (hydraulic jetting)*—when jetting is used for development, a jetting tool with nozzles and a high-pressure pump is used to force water outwardly through the screen, the filter pack, and sometimes into the adjacent geologic unit.

4.1.63 *zone of saturation*—a hydrologic zone in which all the interstices between particles of geologic material or all of the joints, fractures, or solution channels in a consolidated rock unit are filled with water under pressure greater than that of the atmosphere.

5. Site Characterization

5.1 *General*—Soil mechanics, geomorphological concepts, geologic structure, stratigraphy, and sedimentary concepts, as well as the nature and behavior of the solutes of interest, must be combined with a knowledge of ground water movement to make a complete application of the results of the monitoring well design and installation guidance. Therefore, development of a conceptual hydrogeologic model that identifies potential flow paths and the target monitoring zone(s) is recommended prior to monitoring well design and installation. Development of the conceptual model is accomplished in two phases—an initial reconnaissance and a field investigation. When the hydrogeology of a project area is relatively uncomplicated and well documented in the literature, the initial reconnaissance may provide sufficient information to identify flow paths and the target monitoring zone(s). However, where little background data is available or the geology is complicated, a field investigation will generally be necessary to completely develop a conceptual hydrogeologic model.

5.2 *Initial Reconnaissance of Project Area*—The goal of the initial reconnaissance of the project area is to identify and locate those zones with the greatest potential to transmit a fluid from the project area. Identifying these flow paths is the first step in selecting the target ground water monitoring zone(s).

5.2.1 *Literature Search*—Every effort should be made to collect and review all applicable field and laboratory data from previous investigations of the project area. Data such as, but not limited to, topographic maps, aerial imagery, site ownership and utilization records, geologic and hydrogeologic maps and reports, mineral resource surveys, water well logs, personal information from local well drillers, agricultural soil reports, geotechnical engineering reports, and other engineering maps and report related to the project area should be reviewed.

5.2.2 *Field Reconnaissance*—Early in the investigation, the soil and rocks in open cut areas in the vicinity of the project should be studied, and various soil and rock profiles noted. Special consideration should be given to soil color and textural changes, landslides, seeps, and springs within or near the project area.

5.2.3 *Preliminary Conceptual Model*—The distribution of the predominant soil and rock units likely to be found during subsurface exploration may be hypothesized at this time in a preliminary hydrogeologic conceptual model using data obtained in the literature search and field reconnaissance. In areas where the geology is relatively uniform, well documented in the literature, and substantiated by the field reconnaissance, further refinement of the conceptual model may not be necessary unless anomalies are discovered in the well drilling stage.

5.3 *Field Investigation*—The goal of the field investigation is to refine the preliminary conceptual hydrogeologic model so that the target monitoring zone(s) is selected prior to monitoring well installation.

5.3.1 *Exploratory Borings and Test Pits*—Characterization of the flow paths conceptualized in the initial reconnaissance involves defining the porosity, hydraulic conductivity, gradation, stratigraphy, lithology, and structure of each hydrologic unit. The characteristics are defined by conducting an exploratory boring program which may include test pits. Exploratory borings and test pits should be deep enough to develop the required engineering and hydrogeologic data for determining the flow path(s), target monitoring zone, or both.

5.3.1.1 *Sampling*—Soil and rock properties should not be predicted wholly on field identification or classification, but should be checked by laboratory and field tests made on samples. Representative soil or rock samples, or both, of each material that is significant to the analysis and design of the monitoring system should be obtained and evaluated by a geologist, hydrogeologist, or engineer trained and experienced in soil and rock analysis. Soil sample extraction should be conducted according to Practice D 1452, Method D 1586, Practice D 3550, or Practice D 1587, whichever is appropriate given the anticipated characteristics of the soil samples. Rock samples should be extracted according to Practice D 2113. Soil samples obtained for evaluation of hydraulic properties should be containerized and identified for shipment to a laboratory. Special measures to preserve either the continuity of the sample or the natural moisture are not usually required. However, soil and rock samples obtained for evaluation of chemical properties often require special field preparation and preservation to prevent significant alteration of the chemical constituents during transportation to a laboratory (see Practice D 4220). Rock samples for evaluation of hydraulic properties are usually obtained using a split-inner-tube core barrel. Evaluation and logging of the core samples is usually made in the field before the core is removed from half of the split inner tube core barrel.

5.3.1.2 *Boring Logs*—Care should be taken to prepare and retain a complete boring log and sampling record for each exploratory borehole and test pit.

NOTE 1—Site investigations for the installation of ground-water monitoring wells can vary greatly due to the availability of reliable site data or the lack thereof. The general procedure would however be as follows: (*1*) gather factual data regarding the surficial and subsurface conditions, (*2*) analyze the data, (*3*) develop a conceptual model of the site conditions, (*4*) locate the monitoring wells based on the first three steps. Monitoring wells should only be installed with sufficient understanding of the geologic and hydrogeologic conditions present on site. Monitoring wells often serve as part of an overall site investigation for a specific purpose, such as determining the extent of contamination present, or for prediction of the effectiveness of aquifer remediations. In these cases extensive additional geotechnical and hydrogeologic information may be required that would go beyond the Section 5 Site Characterization description.

Boring logs should include the location, geotechnical (that is, penetration rates or blow counts), and sampling information for each material identified in the borehole either by symbol or word description, or both. Identification of all soils should be in accordance with Practice D 2488 or Practice D 3282. Identification of rock material should be based on Nomenclature C 294 or by an appropriate geologic classification system. Observations of seepage, free water, and water levels should also be noted. The boring logs should be accompanied by a report that includes a description of the area investigated; a map illustrating the vertical and horizontal location (with reference to nearest National Geodetic Vertical Datum [NGVD] and to a standardized survey grid, respectively) of each exploratory borehole or test pit, or both; and color photographs of rock cores, soil samples, and exposed strata labeled with a date and identification.

5.3.2 *Geophysical Exploration*—Geophysical surveys may be used to supplement borehole and outcrop data and to aid in interpretation between boreholes. Surface geophysical methods such as seismic surveys, and electrical-resistivity and electromagnetic conductance surveys can be particularly valuable when distinct differences in the properties of contiguous subsurface materials are indicated. Borehole methods such as resistivity, gamma, gamma-gamma, neutron, and caliper logs can be useful to confirm specific subsurface geologic conditions. Gamma logs are particularly useful in existing cased wells.

5.3.3 *Ground Water Flow Direction*—Ground water flow direction is generally determined by measuring the vertical and horizontal hydraulic gradient within each conceptualized flow path. However, because water will flow along the path of least resistance, flow direction may be oblique to the hydraulic gradient (buried stream channels or glacial valleys, for example). Flow direction is determined by first installing piezometers in the exploratory boreholes. The depth and location of the piezometers will depend upon anticipated hydraulic connections between conceptualized flow paths and their respective lateral direction of flow. Following careful evaluation, it may be possible to utilize existing private or public wells to obtain water level data. The construction integrity of such wells should be verified to ensure that the water levels obtained from the wells are representative only of the zones of interest. Following water level data acquisition, a potentiometric surface map should be prepared. Flow paths are ordinarily determined to be at right angles, or nearly so, to the equipotential lines.

5.4 *Completing the Conceptual Model*—A series of hydrogeologic cross sections should be developed to refine the conceptual model. This is accomplished by first plotting logs of soil and rock observed in the exploratory borings or test pits, and interpreting between these logs using the geologic and engineering interrelationships between other soil and rock data observed in the initial reconnaissance or with geophysical techniques. Extrapolation of data into adjacent areas should be done only where geologically uniform subsurface conditions are known to exist. The next step is to integrate the profile data with the piezometer data for both vertical and horizontal hydraulic gradients. Plan view and cross-sectional flow nets may need to be constructed. Following the analysis of these data, conclusions can be made as to which flow path(s) is the appropriate target monitoring zone(s).

NOTE 2—Ground water monitoring is difficult and may not be a reliable technology in fine-grain, low hydraulic conductivity, primary porosity strata because of (*1*) the disproportionate influence that microstratigraphy has on ground water flow in fine-grain strata; (*2*) flow lines proportionally higher for the vertical flow component in low hydraulic conductivity strata; and (*3*) the presence of indigenous metallic and inorganic constituents that make water quality data evaluation difficult.

6. Monitoring Well Construction Materials

6.1 *General*—The materials that are used in the construction of a monitoring well and that come in contact with the water sample should not measurably alter the chemical quality of the sample for the constituents being examined using the appropriate sampling protocols. Furthermore, the riser, well screen, and annular sealant injection equipment should be steam cleaned or high-pressure water cleaned (if appropriate for the selected riser material) immediately prior to well installation or certified clean from the manufacturer and delivered to site in a protective wrapping. Samples of the cleaning water, filter pack, annular seal, and mixed grout should be retained to serve as quality control until the completion of at least one round of ground water quality sampling and analysis.

6.2 *Water*—Water used in the drilling process, to prepare grout mixtures and to decontaminate the well screen, riser, and annular sealant injection equipment, should be obtained from a source of known chemistry that does not contain constituents that could compromise the integrity of the well installation.

6.3 *Primary Filter Pack:*

6.3.1 *Materials*—The primary filter pack (gravel pack) consists of a granular material of known chemistry and selected grain size and gradation that is installed in the annulus between the screen and the borehole wall. The filter pack is usually selected to have a 30 % finer (d-30) grain size that is about 4 to 10 times greater than the 30 % finer (d-30) grain size of the hydrologic unit being filtered (see Fig. 1). Usually, the filter is selected to have a low (that is, less than 2.5) uniformity coefficient. The grain size and gradation of the filter are selected to stabilize the hydrologic unit adjacent to the screen and permit only the finest soil grains to enter the screen during development. Thus, after development, a correctly filtered monitoring well is relatively turbid-free.

NOTE 3—When installing a monitoring well in Karst or highly fractured bedrock, the borehole configuration of void spaces within the formation surrounding the borehole is often unknown. Therefore, the installation of a filter pack becomes difficult and may not be possible.

6.3.2 *Gradation*—The filter pack should be uniformly graded and comprised of hard durable siliceous particles washed and screened with a particle size distribution derived by multiplying the d-30 size of the finest-grained screened stratum by a factor between 4 and 10. Use a number between four and six as the multiplier if the stratum is fine and uniform; use a factor between six and ten where the material has highly nonuniform gradation and includes silt-sized particles. The grain-size distribution of the filter pack is then plotted using the d-30 size as the control point on the graph. The selected filter pack should have a uniformity coefficient of approximately 2.5 or less.

NOTE 4—This practice presents a design for monitoring wells that will be effective in the majority of aquifers. Applicable state guidance may differ from the designs contained in this practice.

NOTE 5—Because the well screen slots have uniform openings, the filter pack should be composed of particles that are as uniform in size as is practical. Ideally, the uniformity coefficient (the quotient of the 60 % passing, D-60 size divided by the 10 % passing D-10 size [effective size]) of the filter pack should be 1.0 (that is, the D-60 % and the D-10 % sizes should be identical). However, a more practical and consistently achievable uniformity coefficient for all ranges of filter pack sizes is 2.5. This value of 2.5 should represent a maximum value, not an ideal.

NOTE 6—Although not recommended as standard practice, often a project requires drilling and installing the well in one phase of work.

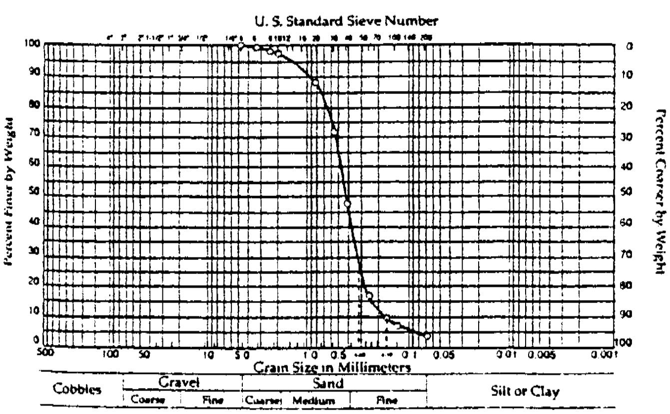

FIG. 1 Example Grading Curve for Design of Monitoring Well Screens

Therefore, the filter pack materials must be ordered and delivered to the drill site before soil samples can be collected. In these cases, the suggested well screen slot size and filter pack materials are presented in Table 1.

6.4 *Well Screen:*

6.4.1 *Materials*—The well screen should be new, machine-slotted or continuous wrapped wire-wound and composed of materials most suited for the monitoring environment and site characterization findings. The screen should be plugged at the bottom. The plug should be of the same material as the well screen. This assembly must have the capability to withstand installation and development stresses without becoming dislodged or damaged. The length of the slotted area should reflect the interval to be monitored. Immediately prior to installation, the well screen should be steam cleaned or high-pressure water cleaned (if appropriate for the selected well screen materials) with water from a source of known chemistry if not certified by the manufacturer, delivered, and maintained clean at the site.

NOTE 7—Well screens are most commonly composed of PVC, stainless steel, fiberglass, or fluoropolymer materials.

6.4.2 *Diameter*—The minimum nominal internal diameter of the well screen should be chosen based on the particular application. However, in most instances, a minimum of 2 in. (50 mm) is needed to allow for the introduction and withdrawal of sampling devices.

6.4.3 *Slot Size*—The slot size of the well screen should be determined relative to the grain size analysis of the stratum interval to be monitored and the gradation of the filter pack material. In granular non-cohesive strata that will fall in easily around the screen, filter packs are not necessary. In these cases of natural development, the slot size of the well screen is to be determined using the grain size of the materials in the surrounding strata. The slot size and arrangement should retain at least 90 % and preferably 99 % of the filter pack. The method for determining the correct gradation of filter pack material is described in 6.3.2.

6.5 *Riser:*

6.5.1 *Materials*—The riser should be new and composed of materials that will not alter the quality of water samples for the constituents of concern and that are appropriate for the monitoring environment. The riser should have adequate wall thickness and coupling strength to withstand installation and development stresses. Each section of riser should be steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a source of known chemistry immediately prior to installation.

NOTE 8—Risers are generally constructed of PVC, stainless steel, fiberglass, or fluoropolymer materials.

6.5.2 *Diameter*—The minimum nominal internal diameter of the riser should be chosen based on the particular application. However, in most instances, a minimum of 2 in. (50 mm) is needed to accommodate sampling devices.

6.5.3 *Joints (Couplings)*—Threaded joints are recommended. Glued or solvent welded joints of any type are *not* recommended since glues and solvents may alter the chemistry of the water samples. In most cases, square profile flush joint threads do not require PTFE taping, however, tapered thread joints should be PTFE taped to prevent leakage of water into the riser. Alternatively, O-rings composed of

TABLE 1 Recommended (Achievable) Filter Pack Characteristics for Common Screen Slot Sizes

Size of Screen Opening, mm (in.)	Slot No.	Sand Pack Mesh Size Name(s)	1 % Passing Size (D-1), mm	Effective Size, (D-10), mm	30 % Passing Size (D-30), mm	Range of Uniformity Coefficient	Roundness (Powers Scale)
0.125 (0.005)	5[A]	100	0.09 to 0.12	0.14 to 0.17	0.17 to 0.21	1.3 to 2.0	2 to 5
0.25 (0.010)	10	20 to 40	0.25 to 0.35	0.4 to 0.5	0.5 to 0.6	1.1 to 1.6	3 to 5
0.50 (0.020)	20	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
0.75 (0.030)	30	10 to 20	0.7 to 0.9	1.0 to 1.2	1.2 to 1.5	1.1 to 1.6	3 to 6
1.0 (0.040)	40	8 to 12	1.2 to 1.4	1.6 to 1.8	1.7 to 2.0	1.1 to 1.6	4 to 6
1.5 (0.060)	60	6 to 9	1.5 to 1.8	2.3 to 2.8	2.5 to 3.0	1.1 to 1.7	4 to 6
2.0 (0.080)	80	4 to 8	2.0 to 2.4	2.4 to 3.0	2.6 to 3.1	1.1 to 1.7	4 to 6

[A] A 5-slot (0.152-mm) opening is not currently available in slotted PVC but is available in Vee wire PVC and Stainless; 6-slot opening may be substituted in these cases.

materials that would not impact the water sample for the constituents of concern may be selected for use on flush joint threads.

6.6 *Casing*—Where conditions warrant, the use of permanent casing installed to prevent communication between water-bearing zones is encouraged. The following subsections address both temporary and permanent casings.

6.6.1 *Materials*—The material type and minimum wall thickness of the casing should be adequate to withstand the forces of installation. All casing that is to remain as a permanent part of the installation (that is, multi-cased wells) should be new and cleaned to be free of interior and exterior protective coatings.

NOTE 9—The exterior casing (temporary or permanent multi-cased) is generally composed of steel, although other appropriate materials may be used.

6.6.2 *Diameter*—Several different casing sizes may be required depending on the subsurface geologic conditions penetrated. The diameter of the casing for filter packed wells should be selected so that a minimum annular space of 2 in. (50 mm) is maintained between the inside diameter of the casing and outside diameter of the riser. In addition, the diameter of the casings in multi-cased wells should be selected so that a minimum annular space of 2 in. is maintained between the casing and the borehole (that is, a 2-in. diameter screen will require first setting a 6-in. (152-mm) diameter casing in a 10-in. (254-mm) diameter boring).

NOTE 10—Under difficult drilling conditions (collapsing soils, rock, or cobbles), it may be necessary to advance temporary casing, under these conditions a smaller annular space may be maintained.

6.6.3 *Joints (Couplings)*—The ends of each casing section should be either flush-threaded or bevelled for welding.

6.7 *Protective Casing:*

6.7.1 *Materials*—Protective casings may be made of aluminum, steel, stainless steel, cast iron, or a structural plastic. The protective casing should have a lid capable of being locked shut by a locking device.

6.7.2 *Diameter*—The inside dimensions of the protective casing should be a minimum of 2 in. (50 mm) and preferably 4 in. (101 mm) larger than the nominal diameter of the riser to facilitate the installation and operation of sampling equipment.

6.8 *Annular Sealants*—The materials used to seal the annulus may be prepared as a slurry or used un-mixed in a dry pellet, granular, or chip form. Sealants should be selected to be compatible with ambient geologic, hydrogeologic, and climatic conditions and any man-induced conditions anticipated to occur during the life of the well.

6.8.1 *Bentonite*—Bentonite should be powdered, granular, pelletized, or chipped sodium montmorillonite furnished in sacks or buckets from a commercial source and free of impurities which adversely impact the water quality in the well. Pellets consist of roughly spherical or disk shaped units of compressed bentonite powder. Chips are large, irregularly shaped, and coarse granular units of bentonite free of additives. The diameter of pellets or chips selected for monitoring well construction should be less than one fifth the width of the annular space into which they are placed to reduce the potential for bridging. Granules consist of coarse particles of unaltered bentonite, typically smaller than 0.2 in. (50 mm).

6.8.2 *Cement*—Each type of cement has slightly different characteristics that may be appropriate under various physical and chemical conditions. Cement should be one of the five Portland cement types that are specified in Specification C 150. The use of quick-setting cements containing additives is not recommended for use in monitoring well installation. Additives may leach from the cement and influence the chemistry of the water samples.

6.8.3 *Grout*—The grout backfill that is placed above the bentonite annular seal and secondary filters (see Fig. 2) is ordinarily a liquid slurry consisting of either a bentonite (powder or granules, or both) base and water, or a Portland cement base and water. Often, bentonite-based grouts are used when it is desired that the grout remain flexible (that is, to accommodate freeze-thaw) during the life of the installation. Cement or bentonite-based grouts are often used when the filling in of cracks in the surrounding geologic material, adherence to rock units, or a rigid setting is desired.

6.8.3.1 *Mixing*—The mixing (and placing) of a grout backfill should be performed with precisely recorded weights and volumes of materials, and according to procedures stipulated by the manufacturer that often include the order of component mixing. The grout should be thoroughly mixed with a paddle type mechanical mixer or by recirculating the mix through a pump until all lumps are disintegrated. Lumpy grout should not be used in the construction of a monitoring well to prevent bridging within the tremie.

NOTE 11—Lumps do not include lost circulation materials that may be added to the grout if excessive grout losses occur.

6.8.3.2 *Typical Bentonite Base Grout*—When a bentonite base grout is used, bentonite, usually unaltered, *must* be the first additive placed in the water through a venturi device. A typical unbeneficiated bentonite base grout consists of about 1 to 1.25 lb (0.57 kg) of unaltered bentonite to each 1 gal (3.8 L) of water. After the bentonite is mixed and allowed to "yield or hydrate," up to 2 lb (0.9 kg) of Type I Portland cement (per gallon of water) is often added to stiffen the mix.

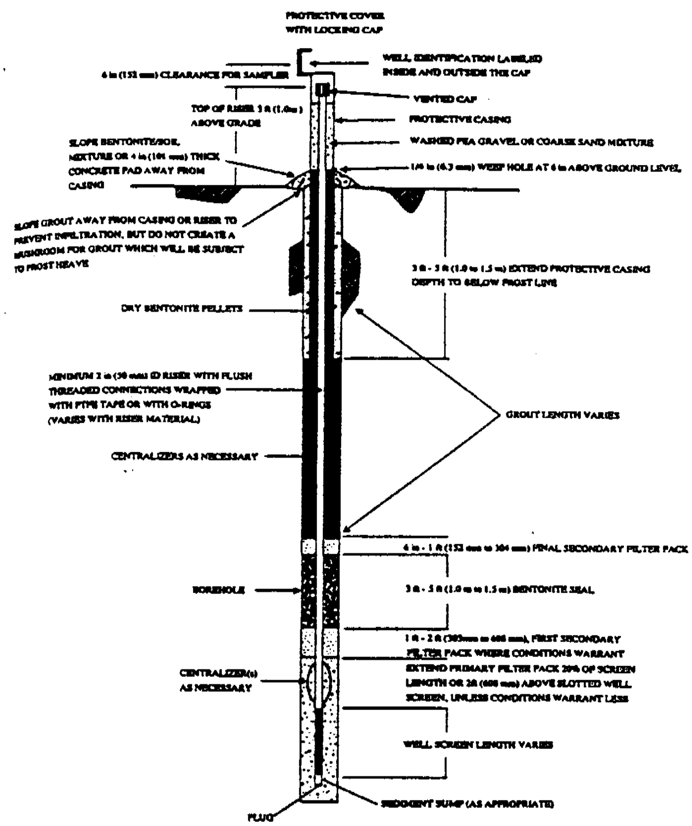

FIG. 2 Monitoring Well Design—Single–Cased Well

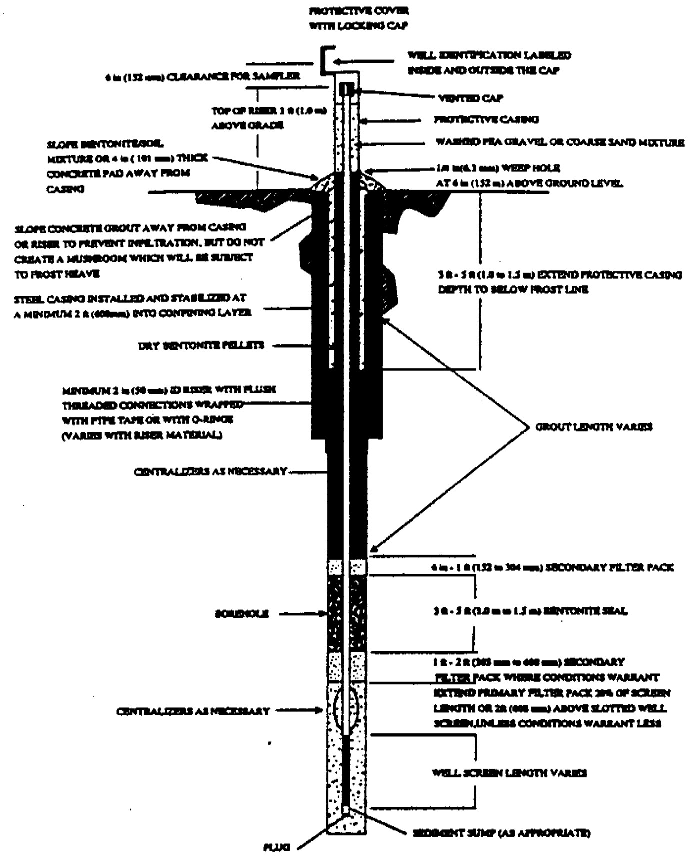

FIG. 3 Monitoring Well Design—Multi–Cased Well

100 % Bentonite grouts should not be used solely for monitoring well annular sealants in the vadose zone of arid regions because of their propensity to desiccate. This could result in non-representative waters affecting the target monitoring zone.

NOTE 12—High solids bentonite grouts (minimum 20 % by weight with water) and other bentonite-based grouts may contain granular bentonite to increase the solids content and other components added under manufacturer's directions to either stiffen or retard stiffening of the mix.

All additives to grouts should be evaluated for their effects on subsequent water samples.

6.8.3.3 *Typical Cement Base Grout*—When a cement-based grout is used, cement is usually the first additive placed in the water. A typical cement-based grout consists of about 6 to 7 gal (23 to 26 L) of water per 94-lb (43-kg) bag of Type I Portland cement. From 0 to 10 % (by dry weight of cement) of unaltered bentonite powder is often added after the initial mixing of cement and water to retard shrinkage and provide plasticity. The bentonite is added *dry* to the cement-water slurry without first mixing it with water.

6.9 *Secondary Filter Packs:*

6.9.1 *Materials*—A secondary filter pack is a layer of material placed in the annulus between the primary filter pack and the bentonite seal, and between the bentonite seal and the grout backfill (see Figs. 2 and 3).

6.9.2 *Gradation*—The secondary filter pack should be uniformly graded fine sand with a 100 % by weight passing the No. 30 U.S. Standard sieve, and less than 2 % by weight passing the 200 U.S. Standard sieve.

6.10 *Annular Seal Equipment*—The equipment used to inject the annular seals and filter pack should be steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a source or known quality prior to use. This procedure is performed to prevent the introduction of materials that may ultimately alter the water sample quality.

7. Drilling Methods

7.1 The type of equipment required to create a stable, open, vertical borehole for installation of a monitoring well depends upon the site geology, hydrology, and the intended use of the data. Engineering and geological judgment is required for the selection of the drilling methods utilized for drilling the exploratory boreholes and monitoring wells. Whenever feasible, drilling procedures should be utilized that do not require the introduction of water or liquid fluids into the borehole, and that optimize cuttings control at ground surface. Where the use of drilling fluid is unavoidable, the selected fluid should have as little impact as possible on the water samples for the constituents of interest. In addition, care should be taken to remove as much drilling fluid as possible from the well and the aquifer during the well development process. It is recommended that if an air compressor is used, it is equipped with an oil air filter or oil trap.

8. Monitoring Well Installation

8.1 *Stable Borehole*—A stable borehole must be constructed prior to attempting to install the monitoring well screen and riser. Steps must be taken to stabilize the borehole before attempting installation if the borehole tends to cave or blow-in, or both. Boreholes that are not straight or are partially obstructed should be corrected prior to attempting the installations described herein.

8.2 *Assembly of Well Screen and Riser:*

8.2.1 *Handling*—The well screen, bottom plug, riser, should be either certified clean from the manufacturer or steam cleaned or high-pressure water cleaned (if appropriate for the selected material) using water from a source of known chemistry immediately prior to assembly. Personnel should take precautions to assure that grease, oil, or other contaminants that may ultimately alter the water sample do not contact any portion of the well screen and riser assembly. As one precaution, for example, personnel should wear a clean pair of cotton or surgical (or equivalent) gloves while handling the assembly.

8.2.2 *Riser Joints (Couplings)*—Flush joint risers with square profile threads normally do not require additional PTFE taping to obtain a water tight seal. In addition, O-rings of known chemistry, selected on the basis of prevailing environmental or physical conditions, may be used to assure a tight seal of flush-joint couplings. Couplings are often tightened by hand; however, if necessary, steam cleaned or high-pressure water cleaned wrenches may be utilized. Precautions should be taken to prevent damage to the threaded joints during installation.

8.3 *Setting the Well Screen and Riser Assembly*—When the well screen and riser assembly is lowered to the predetermined level and held into position, the assembly may require ballast to counteract the tendency to float in the borehole. Ballasting may be accomplished by continuously filling the riser with water from a source of known chemistry or, preferably, water which was previously removed from the borehole. Alternatively, the riser may be slowly pushed into the fluid in the borehole with the aid of hydraulic rams on the drill rig and held in place as additional sections of riser are added to the column. Care must be taken to secure the riser assembly so that personnel safety is assured during the installation. The assembly must be installed straight with the appropriate centralizers to allow for the introduction and withdrawal of sampling devices. Difficulty in maintaining a straight installation may be encountered where the weight of the well screen and riser assembly is significantly less than the buoyant force of the fluid in the borehole. The riser should extend above grade and be capped temporarily to deter entrance of foreign materials during completion operations.

8.4 *Installation of the Primary Filter Pack:*

8.4.1 *Volume of Filter Pack*—The volume of filter pack required to fill the annular space between the well screen and borehole should be computed, measured, and recorded on the well completion diagram during installation. To be effective, the filter pack should extend above the screen for a distance of about 20 % of the length of the well screen but not less than 2 ft (600 mm) (see Figs. 2 and 3). Where there is hydraulic connection between the zone to be monitored and the overlying strata, this upward extension should be gauged to prevent seepage from overlying hydrologic units into the filter pack. Seepage from other units may alter the water sample.

8.4.2 *Placement of Primary Filter Pack*—Placement of the well screen is preceded by placing no less than 2 % and no more than 10 % of the primary filter pack into the bottom of the borehole using a decontaminated, flush threaded, 1-in. (25-mm) minimum internal diameter tremie pipe. Alternatively, the filter pack may be added directly between the riser pipe and the auger or borehole or casing and the top of the filter pack located using a tamper or a weighted line. The well screen and riser assembly is then centered in the borehole using one or more centralizer(s) or alternative centering device located not more than 10 ft (3 m) above the bottom of the well screen (see Figs. 2 and 3). The centralizer should not be located in the bentonite seal. The remaining primary filter pack is then placed in increments as the tremie is gradually raised. As primary filter pack material is poured into the tremie pipe, water from a source of known chemistry may be added to help move the filter pack. The tremie pipe or a weighed line inserted through the tremie pipe can be used to measure the top of the primary filter pack as work progresses. If bridging of the primary filter pack occurs, the bridged material should be broken mechanically prior to proceeding with the addition of more filter pack material. The elevation, volume, and gradation of primary filter pack is recorded on the well completion diagram.

8.4.3 *Withdrawal of the Temporary Casing/Augers*—If used, the temporary casing or hollow stem auger is withdrawn, usually in stipulated increments. Care should be taken to minimize lifting the riser with the withdrawal of the temporary casing/augers. To limit borehole collapse, the temporary casing or hollow stem auger is usually withdrawn until the lower most point on the temporary casing or hollow stem auger is at least 2 ft (608 mm), but no more than 5 ft (1.5 m), above the filter pack for unconsolidated materials, or at least 5 ft, but no more than 10 ft (3.0 m), for consolidated materials. In highly unstable formations, withdrawal intervals may be much less. After each increment, it should be ascertained that the primary filter pack has not been displaced during the withdrawal operation (that is, a weighed measuring device).

8.5 *Placement of First Secondary Filter*—A secondary filter pack may be installed above the primary filter pack to prevent the intrusion of the bentonite grout seal into the primary filter pack (see Figs. 2 and 3). To be effective, a measured and recorded volume of secondary filter material should be added to extend 1 to 2 ft (304 to 608 mm) above the primary filter pack. As with the primary filter, a secondary filter must not extend into an overlying hydrologic unit (see 8.4.1). The well designer should evaluate the need for this filter pack by considering the gradation of the primary filter pack, the hydraulic heads between adjacent units, and the potential for grout intrusion into the primary filter pack. The secondary filter material is poured into the annular space through a decontaminated, flush threaded, 1-in. (25-mm) minimum internal diameter tremie pipe lowered to within 3 ft (1.0 m) of the placement interval. Water from a source of known chemistry may be added to help move the filter pack into its proper location. The tremie pipe or weighed line inserted through the tremie pipe can be used to measure the top of the secondary filter pack as work progresses. The elevation, volume, and gradation of the secondary filter pack is recorded on the well completion diagram.

8.6 *Installation of the Bentonite Seal*—A bentonite pellet or a slurry seal is placed in the annulus between the borehole and the riser pipe on top of the secondary or primary filter pack (see Figs. 2 and 3). This seal retards the movement of cement-based grout backfill into the primary or secondary filter packs. To be effective, the bentonite seal should extend above the filter packs approximately 3 to 5 ft (1.0 to 1.5 m)—depending on local conditions. The bentonite seal should be installed using a tremie pipe lowered to the top of the filter packs and slowly raised as the bentonite pellets or the slurry fill the annular space. Bentonite pellets may bridge and block the tremie pipe in deep wells. In these cases, pellets may be allowed to free-fall into the borehole. As a bentonite pellet seal is poured into the tremie pipe or allowed to free-fall into the borehole, a tamper or weighed line may be necessary to tamp pellets into place. If the seal is installed above the water level, water from a source of known chemistry would be added to allow proper hydration of the annular seal. The tremie pipe or a weighed line inserted through the tremie pipe can be used to measure the top of the bentonite seal as the work progresses. If a bentonite pellet seal is being constructed above the water level, approximately 5 gal (20 L) of water from a source of known chemistry can be poured into the annulus to ensure that the pellets hydrate. Sufficient time should be allowed for the bentonite pellet seal to hydrate or the slurry annular seal to expand prior to grouting the remaining annulus. The volume and elevation of the bentonite seal material should be measured and recorded on the well completion diagram.

8.7 *Final Secondary Filter Pack*—A 6-in. to 1-ft (152 to 304-mm) secondary filter may be placed above the bentonite seal in the same manner described in 8.5 (see Figs. 2 and 3). This secondary filter pack will provide a confining layer over the bentonite seal to limit the downward movement of cement-based grout backfill into the bentonite seal. The volume, elevation, and gradation of this final secondary filter pack should be documented on the well completion diagram.

8.8 *Grouting the Annular Space:*

8.8.1 *General*—Grouting procedures vary with the type of well design. The following procedures will apply to both single- and multi-cased monitoring wells. Paragraphs 8.8.2 and 8.8.3 detail those procedures unique to single- and multi-cased installations, respectively.

8.8.1.1 *Volume of Grout*—The volume and location of grout used to backfill the remaining annular space is recorded on the well completion diagram. An ample volume of grout should be premixed on site to compensate for unexpected losses. The use of alternate grout materials, including grouts containing gravel, may be necessary to control zones of high grout loss.

8.8.1.2 *Injection Procedures*—The grout backfill should be injected under pressure to reduce the chance of leaving voids in the grout, and to displace any liquids and drill cuttings that may remain in the annulus. Depending upon the well design, grouting may be accomplished using a pressure grouting technique or by gravity feed through a tremie pipe. With either method, grout is introduced in one continuous operation until full strength grout flows out at the ground surface without evidence of drill cuttings or fluid. The grout should slope away from the riser or casing at the surface, but care should be taken not to create a grout mushroom that would be subjected to frost heave.

8.8.1.3 *Grout Setting and Curing*—The riser or casing or both should not be disturbed until the grout sets and cures for the amount of time necessary to prevent a break in the seal between the grout and riser or grout and casing or both. The amount of time required will vary with grout content and climatic conditions and should be documented on the well completion diagram.

8.8.2 *Specific Procedures for Single-Cased Wells*—Grouting should begin at a level directly above the final secondary filter pack (see Fig. 2). Grout should be injected using a tremie pipe equipped with a side discharge; this dissipates the fluid-pumping energy against the borehole wall and riser, reducing the potential for infiltration of grout into the primary filter pack. The tremie pipe should be kept full of grout from start to finish with the discharge end of the pipe completely submerged as it is slowly and continuously lifted. Approximately 5 to 10 ft (1.5 to 3.0 m) of tremie pipe should remained submerged until grouting is complete. For deep installations or where the joints or couplings of the selected riser cannot withstand the shear or collapse stress exerted by a full column of grout as it sets, a staged grouting procedure may be considered. If used, the temporary casing or hollow stem auger should be removed in increments immediately following each increment of grout installation and in advance of the time when the grout begins to set. If casing removal does not commence until grout injection is completed, then, after the casing is removed, additional grout may be periodically injected into the annular space to maintain a continuous column of grout up to the ground surface.

8.8.3 *Specific Procedures for Multi-Cased Wells*—If the outer casing of a multi-cased well cannot be driven to form a tight seal between the surrounding stratum (strata) and the casing, it should be installed in a predrilled borehole. After the borehole has penetrated not less than 2 ft (608 mm) of the first targeted confining stratum, the outer casing is lowered to the bottom of the boring and the annular space is filled with grout. Grouting may be accomplished using a pressure grouting method or gravity feed through a tremie pipe. Pressure grouting will require the use of a grout shoe or packer installed at the end of the outer casing to prevent grout from moving up into the casing. If a tremie pipe is used to inject grout into the annular space, it should be equipped with a side discharge. With each alternative, the grout must be allowed to cure and form a seal between the casing and the grout prior to advancing the hole to the next hydrologic unit. This procedure is repeated as necessary to advance the borehole to the desired depth. Upon reaching the final target depth, the riser and screen is set through the inner casing. Subsequent to the placement of the filter packs and bentonite seal, the remaining annular space is grouted as described in 8.8.2 (see Fig. 3).

NOTE 13—When using a packer, pressure may build up during grout injection and force grout up the sides of the packer and into the casing.

8.9 *Well Protection*—Well protection refers specifically to installations made at the ground surface to deter unauthorized entry to the monitoring well and to prevent surface water from entering the annulus.

8.9.1 *Protective Casing*—The protective casing should extend from below the frost line (3 to 5 ft [1.0 to 1.5 m]) below the grade depending on local conditions to slightly above the well casing tip. The protective casing should be initially placed before final set of the grout backfill. The protective casing should be sealed and immobilized in concrete placed around the outside of the protective casing above the set grout backfill. The casing should be positioned and stabilized in a position concentric with the riser (see Figs. 1 and 2). Sufficient clearance, usually 6 in. (152 mm) should be maintained between the lid of the protective casing and the top of the riser to accommodate sampling equipment. A ¼-in. (6.3-mm) diameter weep hole should be drilled in the casing 6 in. above the ground surface to permit water to drain out of the annular space. In cold climates, this hole will also prevent water freezing between the well protector and the well casing. Dry bentonite pellets, granules, or chips should then be placed in the annular space below ground level within the protective casing. Coarse sand or pea gravel or both is placed in the annular space above the dry bentonite pellets and above the weep hole to prevent entry of insects. All materials chosen should be documented on the well completion diagram. The monitoring well identification number should be clearly visible on the inside and outside of the lid of the protective casing.

8.9.2 *Completion of Surface Installation*—The well protection installation may be completed in one of three ways:

8.9.2.1 In areas subject to frost heave, place a soil or bentonite/sand layer adjacent to the protective casing sloped to direct water drainage away from the well.

8.9.2.2 In regions *not* subject to frost heave, a 4-in. (101-mm) thick concrete pad sloped to provide water drainage away from the well may be placed around the installation. Care must be taken not to lock the concrete pad onto the protective casing if subsidence of the surface may occur in the future.

8.9.2.3 Where monitoring well protection must be flushed with the ground, an internal cap should be fitted on top of the riser within the manhole or vault. This cap should be leak-proof so that if the vault or manhole should fill with water, the water will not enter the well casing. Ideally, the manhole cover cap should also be leak-proof.

8.9.3 *Additional Protection*—In areas where there is a high probability of damaging the well (high traffic, heavy equipment, poor visibility), it may be necessary to enhance the normal protection of the monitoring well through the use of posts, markers, signs, etc. The level of protection should meet the damage threat posed by the location of the well.

9. Well Development

9.1 *General*—The development serves to remove the finer grained material from the well screen and filter pack that may otherwise interfere with water quality analyses, restore the ground-water properties disturbed during the drilling process and to improve the hydraulic characteristics of the filter pack and hydraulic communication between the well and the hydrologic unit adjacent to the well screen. Methods of well development vary with the physical characteristics of hydrologic units in which the monitoring well is screened and with the drilling method used.

9.2 *Development Methods*—Methods of development most often used include mechanical surging and bailing or pumping, over-pumping, air-lift pumping, and jetting. An important factor in any method is that the development work be stated slowly and gently and be increased in vigor as the well is developed. Most methods of well development require the application of sufficient energy to disturb the filter pack, thereby freeing the fines and allowing them to be drawn into the well. The coarser fractions then settle around and stabilize the screen. The well development method chosen should be documented on the well completion diagram.

NOTE 14—Any time an air compressor is used, it should be equipped with an oil air filter or oil trap to minimize the introduction of oil into the screen area. The presence of oil would impact the organic constituent concentrations of the water samples.

NOTE 15—Development procedures for wells completed in fine sand and silt strata should involve methods that are relatively gentle so that the strain material will not be incorporated into the filter pack. Vigorous surging for development can produce mixing of the fine strata and filter pack and produce turbid samples from the installation. Also, development methods should be carefully selected based upon the potential contaminant(s) present, quality of waste water generated, and requirements for containerization or treatment of waste water.

9.2.1 *Mechanical Surging*—In this method, water is forced to flow into and out of the well screen by operating a plunger (or surge block) or bailer up and down in the riser. A pump or bailer should then be used to remove the dislodged sediments following surging.

9.2.2 *Over Pumping*—With this method, the monitoring well is pumped at a rate considerably higher than it would be during normal operation. The fine-grain materials would be dislodged from the filter pack and surrounding strata influenced by the higher pumping rate. This method is usually conducted in conjunction with mechanical surging.

9.2.3 *Air Lift Pumping*—In this method, an air lift pump is operated by cycling the air pressure on and off for short periods of time. This operation will provide a surging action that will dislodge fine-grained particles. Applying a steady, low pressure will remove the fines that have been drawn into the well by the surging action. Efforts should be made (that is, through the use of a foot valve) to avoid pumping air into the filter pack and adjacent hydrologic unit because the air may lodge there and inhibit future sampling efforts and may alter ambient water chemistry. Furthermore, application of high air pressures should be avoided to prevent damage to small diameter PVC risers, screens, and filter packs.

9.2.4 *Well Jetting*—Another method of development involves jetting the well screen area with water while simultaneously air-lift pumping the well. However, the water added during this development procedure will alter the natural, ambient water quality and may be difficult to remove. Therefore, the water added should be obtained from a source of known chemistry. Water from the monitoring well being developed may also be used if the suspended sediments are first removed.

9.3 *Duration of Well Development*—Well development should begin after the monitoring well is completely installed and prior to water sampling. Development should be continued until representative water, free of the drilling fluids, cuttings, or other materials introduced during well construction is obtained. Representative water is assumed to have been obtained when pH, temperature, and specific conductivity readings stabilize and the water is visually clear of suspended solids. The minimum duration of well development should vary in accordance with the method used to develop the well. For example, surging and pumping the well may provide a stable, sediment-free sample in a matter of minutes; whereas, bailing the well may require several hours of continuous effort to obtain a clear sample. The duration of well development and the pH, temperature, and specific conductivity readings should be recorded on the well completion diagram.

9.4 *Well Recovery Test*—A well recovery test should be performed immediately after and in conjunction with well development. The well recovery test not only provides an indication of well performance but also provides data for determining the transmissivity of the screened hydrologic unit. Estimates of the hydraulic conductivity of the unit can then be determined. Readings should be taken at intervals suggested in the table below until the well has recovered to 90 % of its static water level.

NOTE 16—If a monitoring well does not recover sufficiently for sampling within a 24-h period and the well has been properly developed, the installation should not generally be used as a monitoring well for detecting or assessing low level organic constituents. The installation may, however, be used for long-term water level monitoring if measurements of shorter frequency water level changes are not required.

10. Installation Survey

10.1 *General*—The vertical and horizontal position of each monitoring well in the monitoring system should be surveyed and subsequently mapped by a licensed surveyor. The well location map should include the location of all monitoring wells in the system and their respective identification numbers, elevations of the top of riser position to be used as the reference point for water level measurements, and the elevations of the ground surface protective installations. The locations and elevations of all permanent benchmark(s) and pertinent boundary marker(s) located on-site or used in the survey should also be noted on the map.

10.2 *Water Level Measurement Reference*—The water level measurement reference point should be permanently marked, for instance, by cutting a V-notch into the top edge of the riser pipe. This reference point should be surveyed in reference to the nearest NGVD reference point.

10.3 *Location Coordinates*—The horizontal location of all monitoring wells (active or decommissioned) should be surveyed by reference to a standardized survey grid or by metes and bounds.

TABLE 2 Suggested Recording Intervals for Well Recovery Tests

Time Since Starting Test	Time Interval
0 to 15 min	1 min
15 to 50 min	5 min
50 to 100 min	10 min
100 to 300 min (5 h)	30 min
300 to 1440 min (24 h)	60 min

11. Monitoring Well Network Report

11.1 To demonstrate that the goals as set forth in Section 1, the Scope, have been met, a monitoring well network report should be prepared. This report should:

11.1.1 Locate the area investigated in terms pertinent to the project. This should include sketch maps or aerial photos on which the exploratory borings, piezometers, sample areas, and monitoring wells are located, as well as topographic items relevant to the determination of the various soil and rock types, such as contours, streambeds, etc. Where feasible, include a geologic map and geologic cross sections of the area being investigated.

11.1.2 Include copies of all well boring test pits and exploratory borehole logs, initial and post-completion water levels, all laboratory test results, and all well completion diagrams.

11.1.3 Include the well installation survey.

11.1.4 Describe and relate the findings obtained in the initial reconnaissance and field investigation (Section 5) to the design and installation procedures selected (Sections 7 to 9) and the surveyed locations (Section 10).

11.1.5 This report should include a recommended decommission procedure that is consistent with the well construction and local regulatory requirements.

12. Keywords

12.1 aquifer; borehole drilling; geophysical exploration; ground water; monitoring well; site investigation

APENDIX B

Groundwater Level Monitoring Protocol

APPENDIX B
Groundwater Water Level Monitoring Protocol

All groundwater level measurements will be made using an electric water level sounder calibrated to the nearest 0.01 foot. The sounder will be cleaned before monitoring and between use in each well using a Liqui-Nox soap (or equivalent) solution wash and potable and distilled water rinses. Measurements will be made to the nearest 0.01 foot relative to an established reference mark at the top of each well casing. Water level depths will be compared, in the field, to previous results and re-measured if significantly different. Water level measurements will be recorded using a permanent ink pen on established forms and subsequently entered into an electronic database. Depth to groundwater measurements will be converted to groundwater elevations (above mean sea level) by subtracting the depth to water from the reference point elevation.

APPENDIX C

Groundwater Sampling Protocol

APPENDIX C
GROUNDWATER SAMPLING PROTOCOL

Prior to collecting groundwater samples from monitoring wells, approximately three to four well casing volumes of groundwater will be removed from each well using a positive displacment piston pump set at least 10 feet above the bottom of the well.

During pumping, temperature, pH, electrical conductivity and total dissolved solids will be measured periodically using field calibrated instrumentation. Groundwater samples will be collected when parameters have stabilized in three consecutive readings. If the field parameters do not stabilize before three casing volumes have been removed, additional groundwater will be bailed until the parameters stabilize. Total water volume removed will be approximated using a 5-gallon bucket or inline flowmeter. In the event the well goes dry before three casing volumes have been removed or before parameters have stabilized, the well will be allowed to recover to at least 80 percent of the static water level before the sample is collected.

Field parameter data will be collected using instruments calibrated to standard solutions at the beginning of each sampling day. Calibration results will be recorded in the field daily report. Deviations in calibration will be noted. Field parameter data will be checked and validated by a Certified Hydrogeologist.

Groundwater samples will be collected following pumping using a Teflon or stainless steel bailer that has been cleaned using a Liqui-Nox soap (or equivalent) solution wash and potable and distilled water rinses. Samples will be decanted from the bailer into properly labeled, laboratory-prepared sample containers. Each sample label will include the well number, project number, date and time sampled, analytical test, preservative (if any) and sampler's initials. Samples will be sealed in sealable plastic bags and placed in a field cooler with ice immediately after collection.

For QA/QC purposes, duplicate samples will be collected in the field from two wells during each sampling event. These samples will be submitted to the laboratory "blind" with a fictitious well designation so the repeatability of the analytical results can be objectively evaluated. Duplicate samples will be collected from the same bailer whenever possible to maximize the representativeness of the analytical results. The label given the duplicate sample will be noted on standard sampling forms and/or in the field daily notes to enable later identification and comparison.

If sampling bailers are used in multiple wells, one equipment blank per day of sampling will be collected to ensure the effectiveness of bailer cleaning between wells. The blank sample will consist of distilled water decanted from a cleaned bailer into a laboratory prepared sample container. The blank sample will be collected between sampling of wells.

All groundwater samples will be submitted to a California Department of Health Services certified laboratory under chain-of-custody protocol within 24 hours of collection.

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Standard Guide for Sampling Groundwater Monitoring Wells[1]

This standard is issued under the fixed designation D 4448; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide covers procedures for obtaining valid, representative samples from groundwater monitoring wells. The scope is limited to sampling and "in the field" preservation and does not include well location, depth, well development, design and construction, screening, or analytical procedures.

1.2 This guide is only intended to provide a review of many of the most commonly used methods for sampling groundwater quality monitoring wells and is not intended to serve as a groundwater monitoring plan for any specific application. Because of the large and ever increasing number of options available, no single guide can be viewed as comprehensive. The practitioner must make every effort to ensure that the methods used, whether or not they are addressed in this guide, are adequate to satisfy the monitoring objectives at each site.

1.3 *This standard does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Summary of Guide

2.1 The equipment and procedures used for sampling a monitoring well depend on many factors. These include, but are not limited to, the design and construction of the well, rate of groundwater flow, and the chemical species of interest. Sampling procedures will be different if analyzing for trace organics, volatiles, oxidizable species, or trace metals is needed. This guide considers all of these factors by discussing equipment and procedure options at each stage of the sampling sequence. For ease of organization, the sampling process can be divided into three steps: well flushing, sample withdrawal, and field preparation of samples.

2.2 Monitoring wells must be flushed prior to sampling so that the groundwater is sampled, not the stagnant water in the well casing. If the well casing can be emptied, this may be done although it may be necessary to avoid oxygen contact with the groundwater. If the well cannot be emptied, procedures must be established to demonstrate that the sample represents groundwater. Monitoring an indicative parameter such as pH during flushing is desirable if such a parameter can be identified.

2.3 The types of species that are to be monitored as well as the concentration levels are prime factors for selecting sampling devices (**1**, **2**).[2] The sampling device and all materials and devices the water contacts must be constructed of materials that will not introduce contaminants or alter the analyte chemically in any way.

2.4 The method of sample withdrawal can vary with the parameters of interest. The ideal sampling scheme would employ a completely inert material, would not subject the sample to negative pressure and only moderate positive pressure, would not expose the sample to the atmosphere, or preferably, any other gaseous atmosphere before conveying it to the sample container or flow cell for on-site analysis.

2.5 The degree and type of effort and care that goes into a sampling program is always dependent on the chemical species of interest and the concentration levels of interest. As the concentration level of the chemical species of analytical interest decreases, the work and precautions necessary for sampling are increased. Therefore, the sampling objective must clearly be defined ahead of time. For example, to prepare equipment for sampling for mg/L (ppm) levels of Total Organic Carbon (TOC) in water is about an order of magnitude easier than preparing to sample for μg/L (ppb) levels of a trace organic like benzene. The specific precautions to be taken in preparing to sample for trace organics are different from those to be taken in sampling for trace metals. No final Environmental Protection Agency (EPA) protocol is available for sampling of trace organics. A short guidance manual, (**3**) and an EPA document (**4**) concerning monitoring well sampling, including considerations for trace organics are available.

2.6 Care must be taken not to cross contaminate samples or monitoring wells with sampling or pumping devices or materials. All samples, sampling devices, and containers must be protected from the environment when not in use. Water level measurements should be made before the well is flushed. Oxidation-reduction potential, pH, dissolved oxygen, and temperature measurements and filtration should all be performed on the sample in the field, if possible. All but temperature measurement must be done prior to any significant atmospheric exposure, if possible.

2.7 The sampling procedures must be well planned and all sample containers must be prepared and labeled prior to going to the field.

3. Significance and Use

3.1 The quality of groundwater has become an issue of national concern. Groundwater monitoring wells are one of

[1] This guide is under the jurisdiction of ASTM Committee D-34 on Waste Management and is the direct responsibility of Subcommittee D34.01 on Sampling and Monitoring.

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[2] The boldface numbers in parentheses refer to a list of references at the end of this guide.

TABLE 1 Typical Container and Preservation Requirements for a Ground-Water Monitoring Program

Sample and Measurement	Volume Required (mL)	Container P—Polyethylene G—Glass	Preservative	Maximum Holding Time
Metals As/Ba/Cd/Cr/Fe Pb/Se/Ag/Mn/Na	1000–2000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Mercury	200–300	P/G (special acid cleaning)	high purity nitric acid to pH <2 +0.05 % $K_2Cr_2O_7$	28 days
Radioactivity alpha/beta/radium	4000	P/G (special acid cleaning)	high purity nitric acid to pH <2	6 months
Phenolics	500–1000	G	cool, 4°C H_2SO_4 to pH <2	28 days
Miscellaneous	1000–2000	P	cool, 4°C	28 days
Fluoride	300–500	P		28 days
Chloride	50–200	P/G		28 days
Sulfate	100–500	P/G		48 hours
Nitrate	100–250	P/G		6 h
Coliform	100	P/G		on site/24 h
Conductivity	100	P/G		on site/6 h
pH	100	P/G		48 h
Turbidity	100	P/G		
Total organic carbon (TOC)	25–100	P/G	cool, 4°C or cool, 4°C HCl or H_2SO_4 to pH <2	24 h 28 days
Pesticides, herbicides and total organic halogen (TOX)	1000–4000	G/TFE-fluorocarbon lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Extractable organics	1000–2000	G/TFE-fluorocarbon-lined cap solvent rinsed	cool, 4°C	7 days/extraction +30 days/analysis
Organic purgeables acrolein/acrylonitrile	25–120	G/vial TFE-fluorocarbon-lined septum	cool, 4°C	14 days 3 days

the more important tools for evaluating the quality of groundwater, delineating contamination plumes, and establishing the integrity of hazardous material management facilities.

3.2 The goal in sampling groundwater monitoring wells is to obtain samples that are truly representative of the aquifer or groundwater in question. This guide discusses the advantages and disadvantages of various well flushing, sample withdrawal, and sample preservation techniques. It reviews the parameters that need to be considered in developing a valid sampling plan.

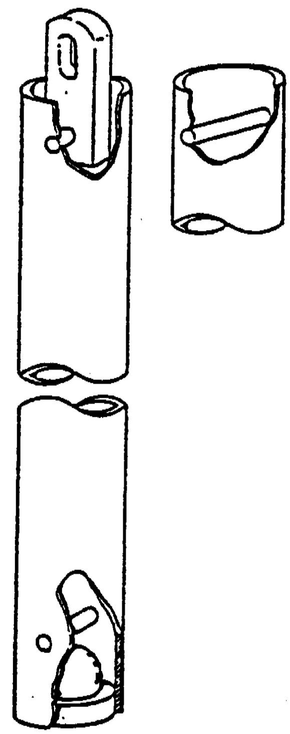
4. Well Flushing (Purging)

4.1 Water that stands within a monitoring well for a long period of time may become unrepresentative of formation water because chemical or biochemical change may cause water quality alterations and even if it is unchanged from the time it entered the well, the stored water may not be representative of formation water at the time of sampling, or both. Because the representativeness of stored water is questionable, it should be excluded from samples collected from a monitoring well.

4.2 The surest way of accomplishing this objective is to remove all stored water from the casing prior to sampling. Research with a tracer in a full scale model 2 in. PVC well (5) indicates that pumping 5 to 10 times the volume of the well via an inlet near the free water surface is sufficient to remove all the stored water in the casing. The volume of the well may be calculated to include the well screen and any gravel pack if natural flow through these is deemed insufficient to keep them flushed out.

4.3 In deep or large diameter wells having a volume of water so large as to make removal of all the water impractical, it may be feasible to lower a pump or pump inlet to some point well below the water surface, purge only the volume below that point then withdraw the sample from a deeper level. Research indicates this approach should avoid most contamination associated with stored water (5, 6, 7). Sealing the casing above the purge point with a packer may make this approach more dependable by preventing migration of stored water from above. But the packer must be above the top of the screened zone, or stagnant water from above the packer will flow into the purged zone through the well's gravel/sand pack.

4.4 In low yielding wells, the only practical way to remove all standing water may be to empty the casing. Since it is not always possible to remove all water, it may be advisable to let the well recover (refill) and empty it again at least once. If introduction of oxygen into the aquifer may be of concern, it would be best not to uncover the screen when performing the above procedures. The main disadvantage of methods designed to remove all the stored water is that large volumes may need to be pumped in certain instances. The main advantage is that the potential for contamination of samples with stored water is minimized.



NOTE—Taken from Ref (15).

FIG. 1 Single Check Valve Bailer

4.5 Another approach to well flushing is to monitor one or more indicator parameters such as pH, temperature, or conductivity and consider the well to be flushed when the indicator(s) no longer change. The advantage of this method is that pumping can be done from any location within the casing and the volume of stored water present has no direct bearing on the volume of water that must be pumped. Obviously, in a low yielding well, the well may be emptied before the parameters stabilize. A disadvantage of this approach is that there is no assurance in all situations that the stabilized parameters represent formation water. If significant drawdown has occurred, water from some distance away may be pulled into the screen causing a steady parameter reading but not a representative reading. Also, a suitable indicator parameter and means of continuously measuring it in the field must be available.

4.6 Gibb (4, 8) has described a time-drawdown approach using a knowledge of the well hydraulics to predict the percentage of stored water entering a pump inlet near the top of the screen at any time after flushing begins. Samples are taken when the percentage is acceptably low. As before, the advantage is that well volume has no direct effect in the duration of pumping. A current knowledge of the well's hydraulic characteristics is necessary to employ this approach. Downward migration of stored water due to effects other than drawdown (for example density differences) is not accounted for in this approach.

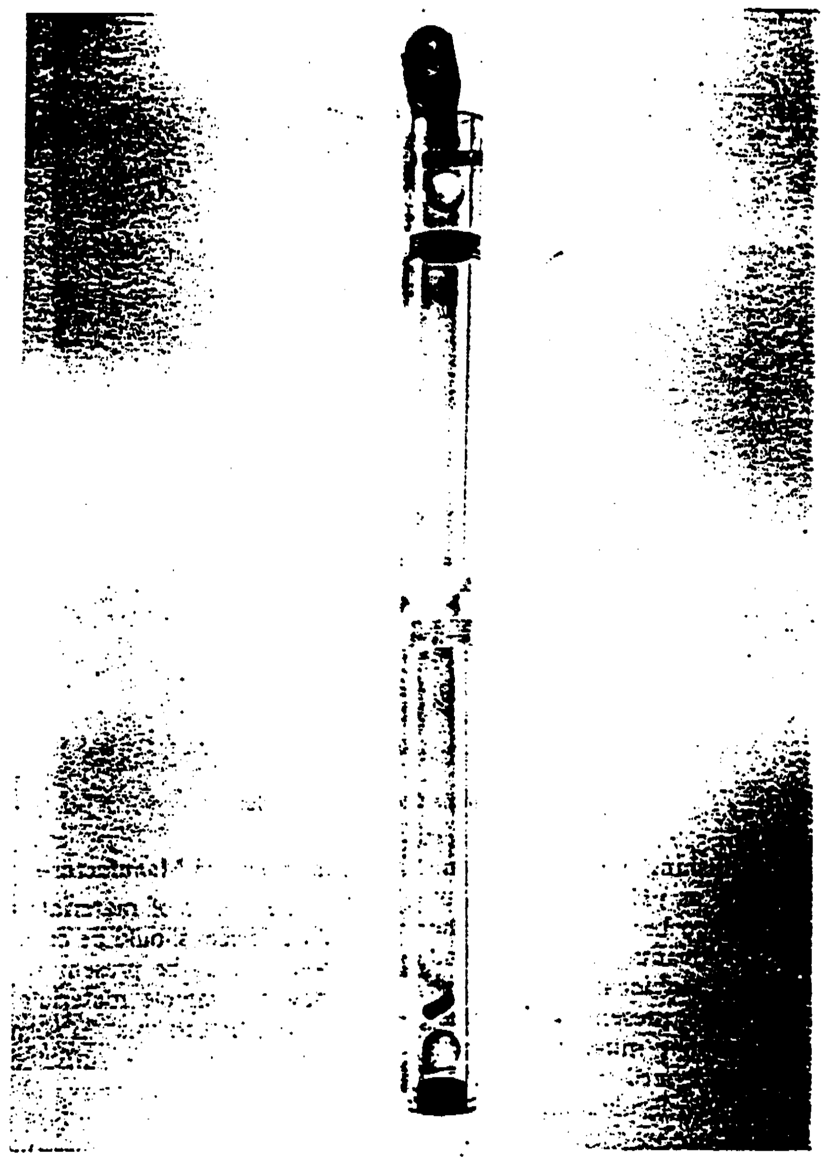
4.7 In any flushing approach, a withdrawal rate that minimizes drawdown while satisfying time constraints should be used. Excessive drawdown distorts the natural flow patterns around a well and can cause contaminants that were not present originally to be drawn into the well.

5. Materials and Manufacture

5.1 The choice of materials used in the construction of sampling devices should be based upon a knowledge of what compounds may be present in the sampling environment and how the sample materials may interact via leaching, adsorption, or catalysis. In some situations, PVC or some other plastic may be sufficient. In others, an all glass apparatus may be necessary.

5.2 Most analytical protocols suggest that the devices used in sampling and storing samples for trace organics analysis (µg/L levels) must be constructed of glass or TFE-fluorocarbon resin, or both. One suggestion advanced by the EPA is that the monitoring well be constructed so that only TFE-fluorocarbon tubing be used in that portion of the sampling well that extends from a few feet above the water table to the bottom of the borehole. (3, 5) Although this type of well casing is now commercially available, PVC well casings are currently the most popular. If adhesives are avoided, PVC well casings are acceptable in many cases although their use may still lead to some problems if trace organics are of concern. At present, the type of background presented by PVC and interactions occurring between PVC and groundwater are not well understood. Tin, in the form of an organotin stabilizer added to PVC, may enter samples taken from PVC casing. (9)

5.3 Since the most significant problem encountered in trace organics sampling, results from the use of PVC adhesives in monitoring well construction, threaded joints might avoid the problem (3, 5). Milligram per litre (parts per million) levels of compounds such as tetrahydrofuran, methyl-ethyl-ketone, and toluene are found to leach into



NOTE—Taken from Ref (17).

FIG. 2 Acrylic Point Source Bailer

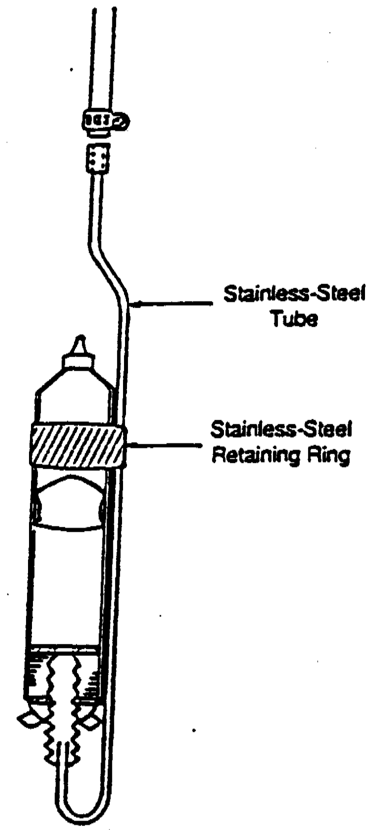
groundwater samples from monitoring well casings sealed with PVC solvent cement. Pollutant phthalate esters (8, 10) are often found in water samples at ppb levels; the EPA has found them on occasion at ppm levels in their samples. The ubiquitous presence of these phthalate esters is unexplained, except to say that they may be leached from plastic pipes, sampling devices, and containers.

5.4 TFE-fluorocarbon resins are highly inert and have sufficient mechanical strength to permit fabrication of sampling devices and well casings. Molded parts are exposed to high temperature during fabrication which destroys any organic contaminants. The evolution of fluorinated compounds can occur during fabrication, will cease rapidly, and does not occur afterwards unless the resin is heated to its melting point.

5.5 Extruded tubing of TFE-fluorocarbon for sampling may contain surface traces of an organic solvent extrusion aid. This can be removed easily by the fabricator and, once removed by flushing, should not affect the sample. TFE-fluorocarbon FEP and TFE-fluorocarbon PFA resins do not require this extrusion aid and may be suitable for sample tubing as well. Unsintered thread-sealant tape of TFE-fluorocarbon is available in an "oxygen service" grade and contains no extrusion aid and lubricant.

5.6 Louneman, et al. (11) alludes to problems caused by a lubricating oil used during TFE-fluorocarbon tubing extrusion. This reference also presents evidence that a fluorinated ethylene-propylene copolymer adsorbed acetone to a degree that later caused contamination of a gas sample.

5.7 Glass and stainless steel are two other materials generally considered inert in aqueous environments. Glass is probably among the best choices though it is not inconceivable it could adsorb some constituents as well as release other contaminants (for example, Na, silicate, and Fe). Of course, glass sampling equipment must be handled carefully in the field. Stainless steel is strongly and easily machined to



NOTE—Taken from Ref (21).

FIG. 3 Schematic of the Inverted Syringe Sampler

fabricate equipment. Unfortunately, it is not totally immune to corrosion that could release metallic contaminants. Stainless steel contains various alloying metals, some of these (for example Ni) are commonly used as catalysts for various reactions. The alloyed constituents of some stainless steels can be solubilized by the pitting action of nonoxidizing anions such as chloride, fluoride, and in some instances sulfate, over a range of pH conditions. Aluminum, titanium, polyethylene, and other corrosion resistant materials have been proposed by some as acceptable materials, depending on groundwater quality and the constituents of interest.

5.8 Where temporarily installed sampling equipment is used, the sampling device that is chosen should be nonplastic (unless TFE-fluorocarbon), cleanable of trace organics, and must be cleaned between each monitoring well use in order to avoid cross-contamination of wells and samples. The only way to ensure that the device is indeed "clean" and acceptable is to analyze laboratory water blanks and field water blanks that have been soaked in and passed through the sampling device to check for the background levels that may result from the sampling materials or from field conditions. Thus, all samplings for trace materials should be accompanied by samples which represent the field background (if possible), the sampling equipment background, and the laboratory background.

5.9 Additional samples are often taken in the field and spiked (spiked-field samples) in order to verify that the sample handling procedures are valid. The American Chemical Society's committee on environmental improvement has published guidelines for data acquisition and data evaluation which should be useful in such environmental evaluations (**10, 12**).

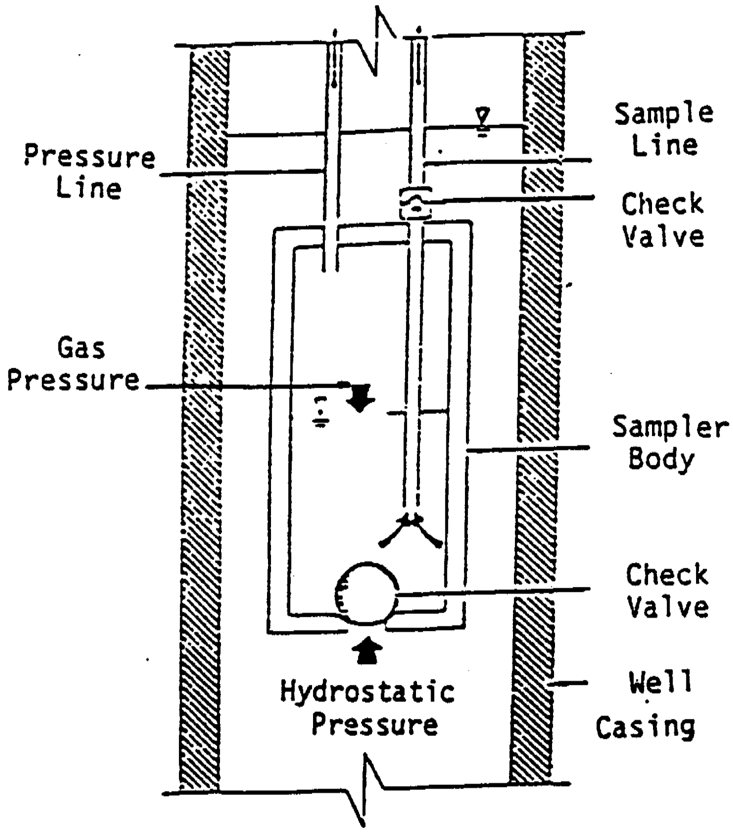
6. Sampling Equipment

6.1 There is a fairly large choice of equipment presently available for groundwater sampling from single screened wells and well clusters. The sampling devices can be categorized into the following eight basic types.

6.1.1 *Down-Hole Collection Devices:*

6.1.1.1 Bailers, messenger bailers, or thief samplers (**13, 14**) are examples of down-hole devices that probably provide valid samples once the well has been flushed. They are not practical for removal of large volumes of water. These devices can be constructed in various shapes and sizes from a variety of materials. They do not subject the sample to pressure extremes.

6.1.1.2 Bailers do expose part of the sample to the atmosphere during withdrawal. Bailers used for sampling of volatile organic compounds should have a sample cock or draft valve in or near the bottom of the sampler allowing withdrawal of a sample from the well below the exposed surface of the water or the first few inches of the sample should be discarded. Suspension lines for bailers and other samplers should be kept off the ground and free of other contaminating materials that could be carried into the well. Down-hole devices are not very practical for use in deep



NOTE—Taken from Ref (5).

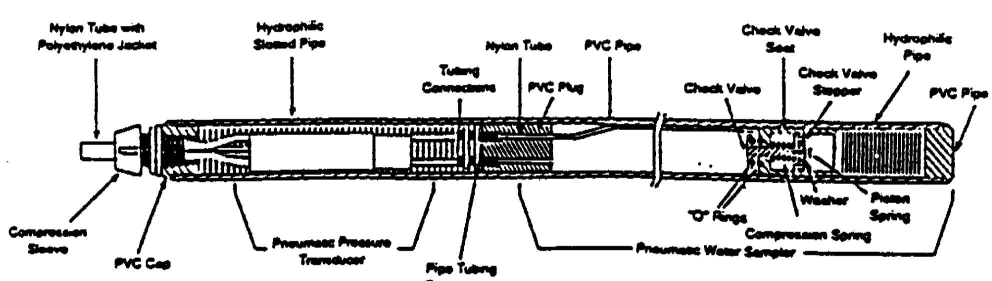
FIG. 4 The Principal of Gas Displacement Pumping

wells. However, potential sample oxidation during transfer of the sample into a collection vessel and time constraints for lowering and retrieval for deep sampling are the primary disadvantages.

6.1.1.3 Three down-hole devices are the single and double check valve bailers and thief samplers. A schematic of a single check valve unit is illustrated in Fig. 1. The bailer may be threaded in the middle so that additional lengths of blank casing may be added to increase the sampling volume. TFE-fluorocarbon or PVC are the most common materials used for construction (15).

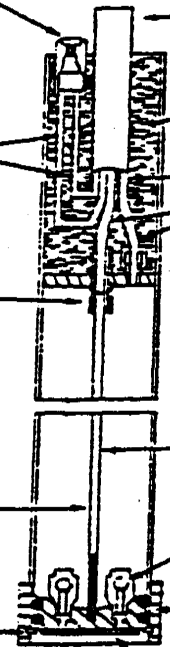
6.1.1.4 In operation, the single check valve bailer is lowered into the well, water enters the chamber through the bottom, and the weight of the water column closes the check valve upon bailer retrieval. The specific gravity of the ball should be about 1.4 to 2.0 so that the ball almost sits on the check valve seat during chamber filling. Upon bailer withdrawal, the ball will immediately seat without any samples loss through the check valve. A similar technique involves lowering a sealed sample container within a weighted bottle into the well. The stopper is then pulled from the bottle via a line and the entire assembly is retrieved upon filling of the container (14, 16).

6.1.1.5 A double check valve bailer allows point source sampling at a specific depth (15, 17). An example is shown in Fig. 2. In this double check valve design, water flows through the sample chamber as the unit is lowered. A venturi tapered inlet and outlet ensures that water passes freely through the



NOTE—Taken from Ref (41).

FIG. 5 Pneumatic Water Sampler With Internal Transducer



NOTE—Taken from Ref (42).

FIG. 6 Pneumatic Sampler With Externally Mounted Transducer

unit. When a depth where the sample is to be collected is reached, the unit is retrieved. Because the difference between each ball and check valve seat is maintained by a pin that blocks vertical movement of the check ball, both check valves close simultaneously upon retrieval. A drainage pin is placed into the bottom of the bailer to drain the sample directly into a collection vessel to reduce the possibility of air oxidation. The acrylic model in Fig. 2 is threaded at the midsection allowing the addition of threaded casing to increase the sampling volume.

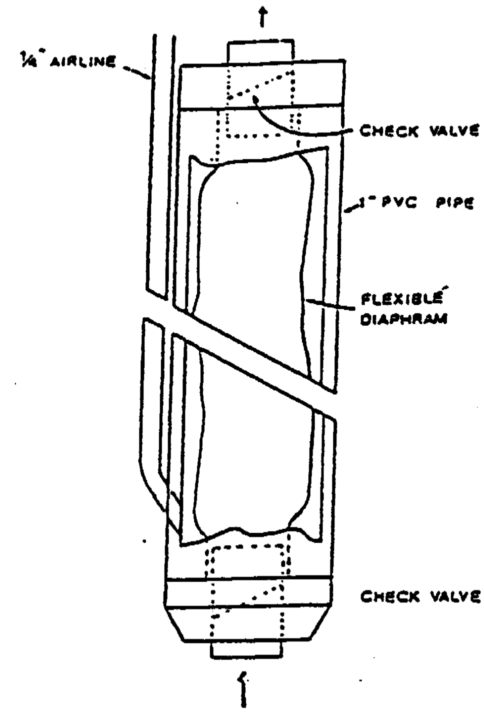
6.1.1.6 Another approach for obtaining point source samples employs a weighted messenger or pneumatic change to "trip" plugs at either end of an open tube (for example, tube water sampler or thief sampler) to close the chamber (18). Foerst, Kemmerer, and Bacon samplers are of this variety (14, 17, 19). A simple and inexpensive pneumatic sampler was recently described by Gillham (20). The device (Fig. 3) consists of a disposable 50 mL plastic syringe modified by sawing off the plunger and the finger grips. The syringe is then attached to a gas-line by means of a rubber stopper assembly. The gas-line extends to the surface, and is used to drive the stem-less plunger, and to raise and lower the syringe into the hole. When the gas-line is pressurized, the rubber plunger is held at the tip of the syringe. The sampler is then lowered into the installation, and when the desired depth is reached, the pressure in the gas-line is reduced to atmospheric (or slightly less) and water enters the syringe. The sampler is then retrieved from the installation and the syringe detached from the gas-line. After the tip is sealed, the syringe is used as a short-term storage container. A number of thief or messenger devices are available in various materials and shapes.

6.1.2 *Suction Lift Pumps:*

6.1.2.1 Three types of suction lift pumps are the direct line, centrifugal, and peristaltic. A major disadvantage of any suction pump is that it is limited in its ability to raise water by the head available from atmospheric pressure. Thus, if the surface of the water is more than about 25 ft below the pump, water may not be withdrawn. The theoretical suction limit is about 34 ft, but most suction pumps are capable of maintaining a water lift of only 25 ft or less.

6.1.2.2 Many suction pumps draw the water through some sort of volute in which impellers, pistons, or other devices operate to induce a vacuum. Such pumps are probably unacceptable for most sampling purposes because they are usually constructed of common materials such as brass or mild steel and may expose samples to lubricants. They often induce very low pressures around rotating vanes or other such parts such that degassing or even cavitation may occur. They can mix air with the sample via small leaks in the casing, and they are difficult to adequately clean between uses. Such pumps are acceptable for purging of wells, but should not generally be used for sampling.

6.1.2.3 One exception to the above statements is a peristaltic pump. A peristaltic pump is a self-priming, low volume suction pump which consists of a rotor with ball bearing rollers (21). Flexible tubing is inserted around the pump rotor and squeezed by heads as they revolve in a circular pattern around the rotor. One end of the tubing is placed into the well while the other end can be connected



NOTE—Taken from Ref (4).

FIG. 7 Bladder Pump

directly to a receiving vessel. As the rotor moves, a reduced pressure is created in the well tubing and an increased pressure (<40 psi) on the tube leaving the rotor head. A drive shaft connected to the rotor head can be extended so that multiple rotor heads can be attached to a single drive shaft.

6.1.2.4 The peristaltic pump moves the liquid totally within the sample tube. No part of the pump contacts the liquid. The sample may still be degassed (cavitation is unlikely) but the problems due to contact with the pump mechanism are eliminated. Peristaltic pumps do require a fairly flexible section of tubing within the pumphead itself. A section of silicone tubing is commonly used within the peristaltic pumphead, but other types of tubing can be used particularly for the sections extending into the well or from the pump to the receiving container. The National Council of the Paper Industry for Air and Stream Improvement (22) recommends using medical grade silicone tubing for organic sampling purposes as the standard grade uses an organic vulcanizing agent which has been shown to leach into samples. Medical grade silicone tube is, however, limited to use over a restricted range of ambient temperatures. Various manufacturers offer tubing lined with TFE-fluorocarbon or Viton[3] for use with their pumps. Gibb (1, 8) found little difference between samples withdrawn by a peristaltic pump and those taken by a bailer.

6.1.2.5 A direct method of collecting a sample by suction consists of lowering one end of a length of plastic tubing into the well or piezometer. The opposite end of the tubing is connected to a two way stopper bottle and a hand held or mechanical vacuum pump is attached to a second tubing leaving the bottle. A check valve is attached between the two lines to maintain a constant vacuum control. A sample can then be drawn directly into the collection vessel without contacting the pump mechanism (5, 23, 24).

6.1.2.6 A centrifugal pump can be attached to a length of plastic tubing that is lowered into the well. A foot valve is usually attached to the end of the well tubing to assist in priming the tube. The maximum lift is about 4.6 m (15 ft) for such an arrangement (23, 25, 26).

6.1.2.7 Suction pump approaches offer a simple sample retrieval method for shallow monitoring. The direct line method is extremely portable though considerable oxidation and mixing may occur during collection. A centrifugal pump will agitate the sample to an even greater degree although pumping rates of 19 to 151 Lpm (5 to 40 gpm) can be attained. A peristaltic pump provides a lower sampling rate with less agitation than the other two pumps. The withdrawal rate of peristaltic pumps can be carefully regulated by adjustment of the rotor head revolution.

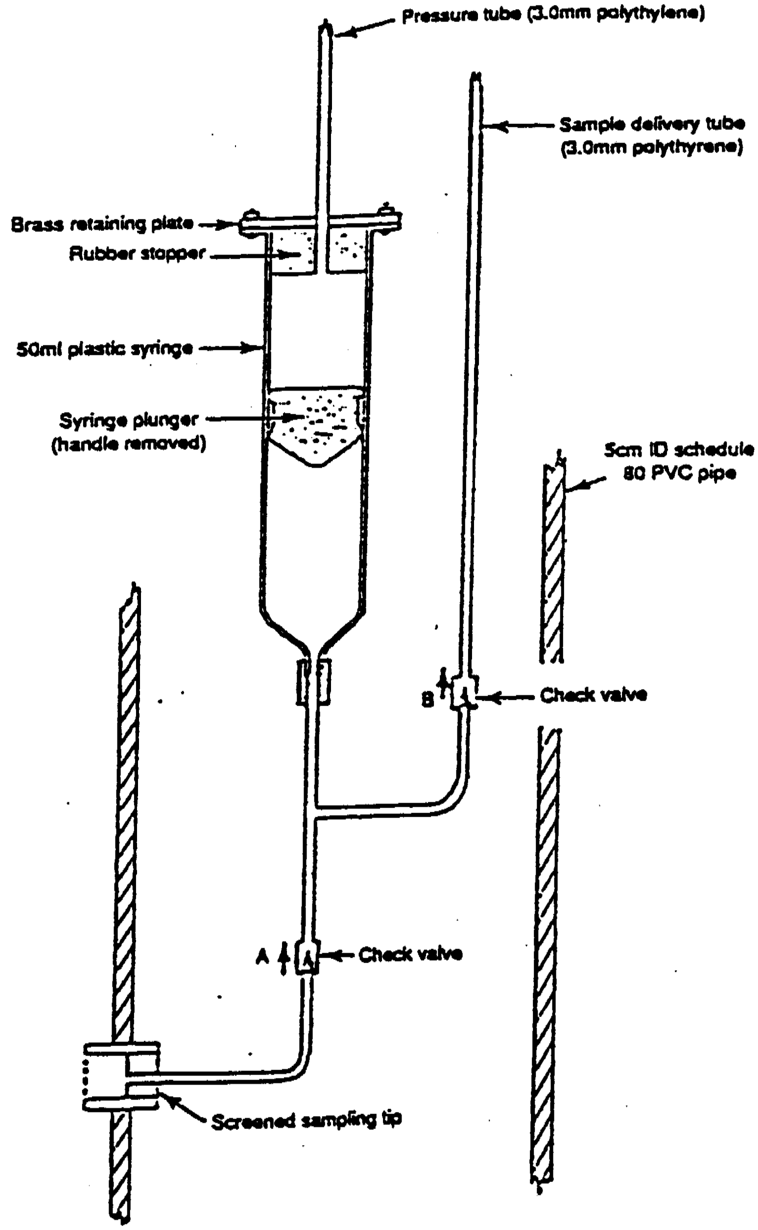
6.1.2.8 All three systems can be specially designed so that the water sample contacts only the TFE flourocarbon or silicone tubing prior to sample bottle entry. Separate tubing is recommended for each well or piezometer sampled.

6.1.3 *Electric Submersible Pumps:*

6.1.3.1 A submersible pump consists of a sealed electric motor that powers a piston or helical single thread worm at a high rpm. Water is brought to the surface through an access tube. Such pumps have been used in the water well industry for years and many designs exist (5, 26).

6.1.3.2 Submersible pumps provide relatively high discharge rates for water withdrawal at depths beyond suction

[3] Viton is a trademark of E. I. du Pont de Nemours & Co., Wilmington, DE 19898 and has been found suitable for this purpose.



NOTE—Taken from Ref (48).

FIG. 8 Positive Displacement Syringe Pump

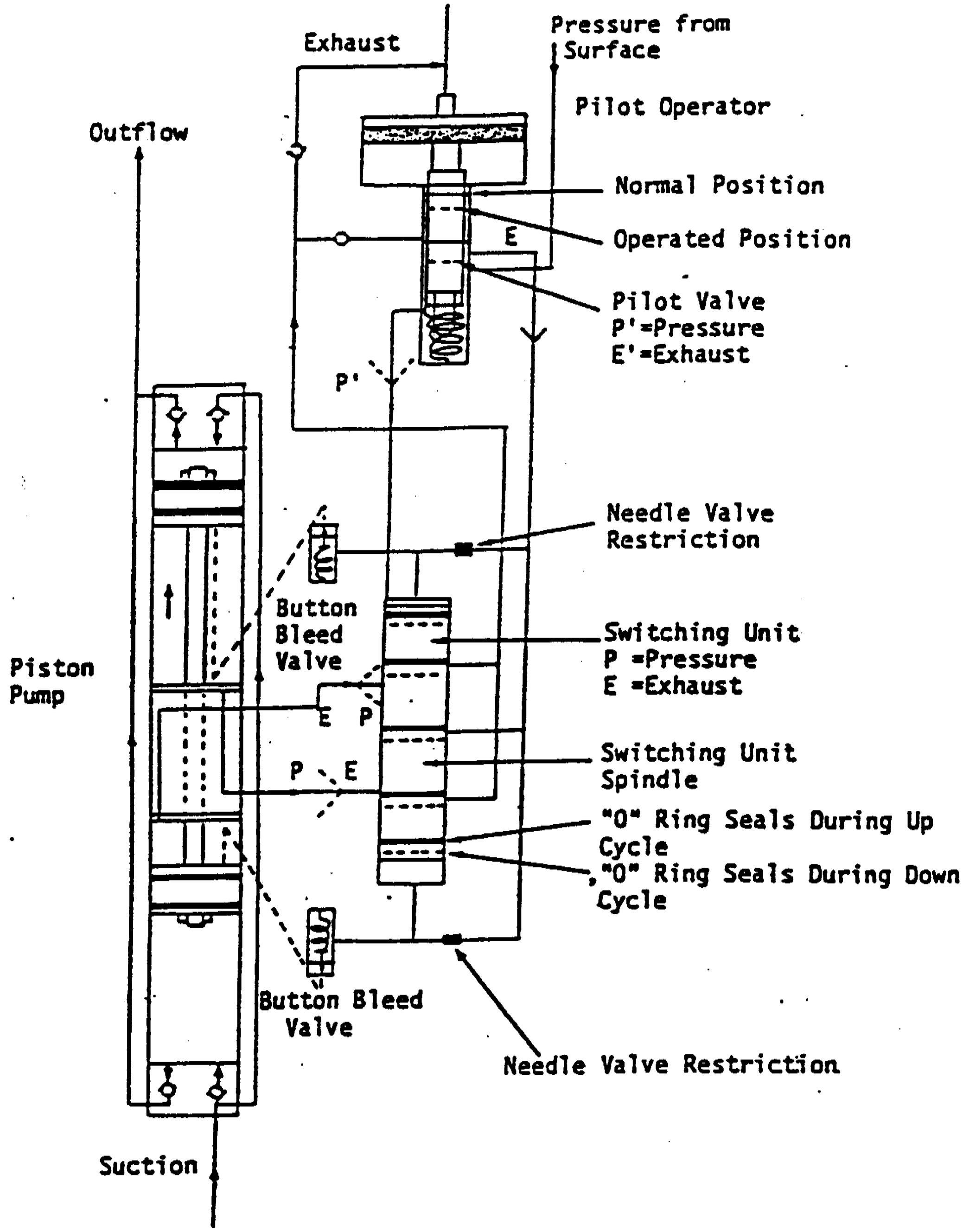
lift capabilities. A battery operated unit 3.6 cm (1.4 in.) in diameter and with a 4.5 Lpm (1.2 gpm) flow rate at 33.5 m (110 ft) has been developed (27). Another submersible pump has an outer diameter of 11.4 cm (4.5 in.) and can pump water from 91 m (300 ft). Pumping rates vary up to 53.0 Lpm (14 gpm) depending upon the depth of the pump (28).

6.1.3.3 A submersible pump provides higher extraction rates than many other methods. Considerable sample agitation results, however, in the well and in the collection tube during transport. The possibility of introducing trace metals into the sample from pump materials also exists. Steam cleaning of the unit followed by rinsing with unchlorinated, deionized water is suggested between sampling when analysis for organics in the parts per million (ppm) or parts per billion (ppb) range is required (29).

6.1.4 *Gas-Lift Pumps:*

6.1.4.1 Gas-lift pumps use compressed air to bring a water sample to the surface. Water is forced up an eductor pipe that may be the outer casing or a smaller diameter pipe inserted into the well annulus below the water level (30, 31).

6.1.4.2 A similar principle is used for a unit that consists of a small diameter plastic tube perforated in the lower end. This tube is placed within another tube of slightly larger diameter. Compressed air is injected into the inner tube; the air bubbles through the perforations, thereby lifting the water sample via the annulus between the outer and inner tubing (32). In practice, the eductor line should be submerged to a depth equal to 60 % of the total submerged eductor length during pumping (26). A 60 % ratio is considered optimal although a 30 % submergence ratio is adequate.



NOTE—Taken from Ref (49).

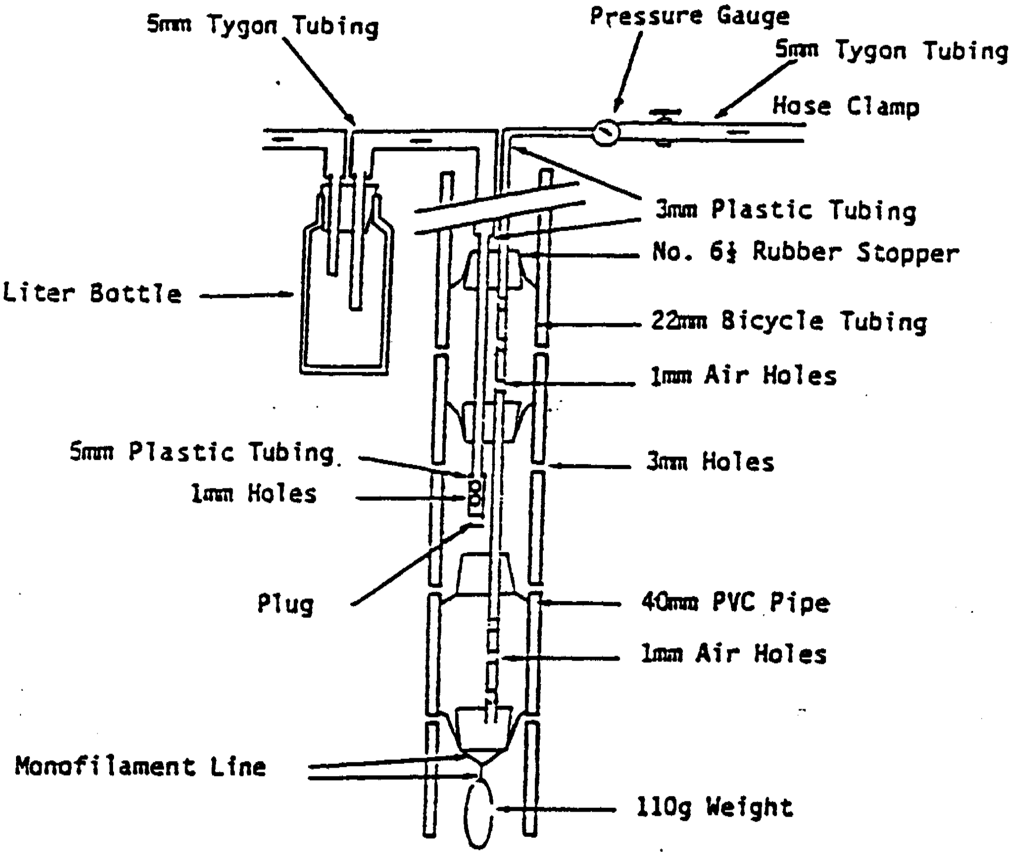
FIG. 9 Gas Driven Piston Pump

6.1.4.3 The source of compressed gas may be a hand ump for depths generally less than 7.6 m (25 ft). For greater epths, air compressors, pressurized air bottles, and air ompressed from an automobile engine have been used.

6.1.4.4 As already mentioned, gas-lift methods result in onsiderable sample agitation and mixing within the well, nd cannot be used for samples which will be tested for olatile organics. The eductor pipe or weighted plastic tubing a potential source of sample contamination. In addition, iibb (8) uncovered difficulties in sampling for inorganics. hese difficulties were attributed to changes in redox, pH, and species transformation due to solubility constant changes resulting from stripping, oxidation, and pressure changes.

6.1.5 *Gas Displacement Pumps:*

6.1.5.1 Gas displacement or gas drive pumps are distinguished from gas-lift pumps by the method of sample transport. Gas displacement pumps force a discrete column of water to the surface via mechanical lift without extensive mixing of the pressurized gas and water as occurs with air-lift equipment. The principle is shown schematically in Fig. 4. Water fills the chamber. A positive pressure is applied to the



NOTE—Taken from Ref (53).

FIG. 10 Packer Pump Arrangement

gas line closing the sampler check valve and forcing water up the sample line. By removing the pressure the cycle can be repeated. Vacuum can also be used in conjunction with the gas (30). The device can be permanently installed in the well (33, 34, 35) or lowered into the well (36, 37).

6.1.5.2 A more complicated two stage design constructed of glass with check valves made of TFE-fluorocarbon has been constructed (38, 39). The unit was designed specifically for sample testing for trace level organics. Continuous flow rates up to 2.3 Lpm (0.6 gpm) are possible with a 5.1 cm (2 in.) diameter unit.

6.1.5.3 Gas displacement pumps have also been developed with multiple functions. The water sample in Fig. 5 provides piezometric data measurements with an internally mounted transducer (40). A sample with its transducer exposed externally for piezometric measurements is illustrated in Fig. 6 (41). The sensor can activate the gas source at the surface to cause sample chamber pressurization at the predetermined depth. Another design can be used as a water sampler or as a tool for injecting brine or other tracers into a well (42).

6.1.5.4 Gas displacement pumps offer reasonable potential for preserving sample integrity because little of the driving gas comes in contact with the sample as the sample is conveyed to the surface by a positive pressure. There is, however, a potential loss of dissolved gasses or contamination from the driving gas and the housing materials.

6.1.6 *Bladder Pumps:*

6.1.6.1 Bladder pumps, also referred to as gas-operated squeeze pumps, consist of a flexible membrane enclosed by a rigid housing. Water enters the membrane through a check valve in the vessel bottom; compressed gas injected into the cavity between the housing and bladder forces the sample through a check valve at the top of the membrane and into a discharge line (Fig. 7). Water is prevented from re-entering the bladder by the top check valve. The process is repeated to cycle the water to the surface. Samples taken from depths of 30.5 m (100 ft) have been reported.

6.1.6.2 A variety of design modifications and materials are available (43, 44). Bladder materials include neoprene, rubber, ethylene propylene terpolymer (E.P.T.), nitrile, and the fluorocarbon Viton.[3] A bladder made of TFE-fluorocarbon is also under development (45). Automated sampling systems have been developed to control the time between pressurization cycles (46).

6.1.6.3 Bladder pumps provide an adaptable sampling tool due primarily to the number of bladder shapes that are feasible. These devices have a distinct advantage over gas displacement pumps in that there is no contact with the driving gas. Disadvantages include the large gas volumes required, low pumping rates, and potential contamination from many of the bladder materials, the rigid housing, or both.

6.1.7 *Gas Driven Piston Pumps:*

6.1.7.1 A simple and inexpensive example of a gas driven piston pump is a syringe pump (47). The pump (Fig. 8) is constructed from a 50 mL plastic syringe with plunger stem removed. The device is connected to a gas line to the surface and the sample passes through a check valve arrangement to a sampling container at the surface. By successively applying positive and negative pressure to the gas-line, the plunger is activated driving water to the surface.

6.1.7.2 A double piston pump powered by compressed air is illustrated in Fig. 9. Pressurized gas enters the chamber between the pistons; the alternating chamber pressurization activates the piston which allows water entry during the suction stroke of the piston and forces the sample to the surface during the pressure stroke (48). Pumping rates between 9.5 and 30.3 L/hr (2.5 to 8. gal/hr) have been reported from 30.5 m (100 ft). Depths in excess of 457 m (1500 ft) are possible.

6.1.7.3 The gas piston pump provides continuous sample withdrawal at depths greater than is possible with most other approaches. Nevertheless, contribution of trace elements from the stainless steel and brass is a potential problem and the quantity of gas used is significant.

6.1.8 *Packer Pump Arrangement:*

6.1.8.1 A packer pump arrangement provides a means by which two expandable "packers" isolate a sampling unit between two packers within a well. Since the hydraulic or pneumatic activated packers are wedged against the casing wall or screen, the sampling unit will obtain water samples only from the isolated well portion. The packers are deflated for vertical movement within the well and inflated when the desired depth is attained. Submersible, gas lift, and suction pumps can be used for sampling. The packers are usually constructed from some type of rubber or rubber compound (**48, 49, 50, 51**). A packer pump unit consisting of a vacuum sampler positioned between two packers is illustrated in Fig. 10 (**52**).

6.1.8.2 A packer assembly allows the isolation of discrete sampling points within a well. A number of different samplers can be situated between the packers depending upon the analytical specifications for sample testing. Vertical movement of water outside the well casing during sampling is possible with packer pumps but depends upon the pumping rate and subsequent disturbance. Deterioration of the expandable materials will occur with time with the increased possibility of undesirable organic contaminants contributing to the water sample.

7. Sample Containers and Preservation

7.1 Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is practically impossible. At best, preservation techniques only retard the chemical and biological changes that inevitably continue after the sample is removed from the source. Therefore, insuring the timely analysis of a sample should be one of the foremost considerations in the sampling plan schedule. Methods of preservation are somewhat limited and are intended to retard biological action, retard hydrolysis of chemical compounds and complexes, and reduce the volatility of constituents. Preservation methods are generally limited to pH control, chemical addition, refrigeration and freezing. For water samples, immediate refrigeration just above freezing (4°C in wet ice) is often the best preservation technique available, but it is not the only measure nor is it applicable in all cases. There may be special cases where it might be prudent to include a recording thermometer in the sample shipment to verify the maximum and minimum temperature to which the samples were exposed. Inexpensive devices for this purpose are available.

7.2 All bottles and containers must be specially precleaned, pre-labelled, and organized in ice-chests (isolating samples and sampling equipment from the environment) before one goes into the field. Otherwise, in any comprehensive program utter chaos usually develops in the field or laboratory. The time in the field is very valuable and should be spent on taking field notes, measurements, and in documenting samples, not on labelling and organizing samples. Therefore, the sampling plan should include clear instructions to the sampling personnel concerning the information required in the field data record logbook (notebook), the information needed on container labels for identification, the chain-of-custody protocols, and the methods for preparing field blanks and spiked samples. Example of detailed plans and documentation procedures have been published (**14, 53**).

7.3 The exact requirements for the volumes of sample needed and the number of containers to use may vary from laboratory to laboratory. This will depend on the specific analyses to be performed, the concentration levels of interest, and the individual laboratory protocols. The manager of the sampling program should make no assumptions about the laboratory analyses. He should discuss the analytical requirements of the sampling program in detail with the laboratory coordinator beforehand. This is especially the case since some analyses and preservation measures must be performed at the laboratory as soon as possible after the samples arrive. Thus, appropriate arrangements must be made.

7.4 There are a number of excellent references available which list the containers and preservation techniques appropriate for water and soils (**13, 14, 50, 54, 55, 56**). The "Handbook for Sampling and Sample Preservation of Water and Wastewater" is an excellent reference and perhaps the most comprehensive one (**14**). Some of this information is summarized in Table 1.

7.5 Sample containers for trace organic samples require special cleaning and handling considerations (57). The sample container for purgeable organics consist of a screw-cap vial (25 to 125 mL) fitted with a TFE-flourocarbon faced silicone septum. The vial is sealed in the laboratory immediately after cleaning and is only opened in the field just prior to pouring sample into it. The water sample then must be sealed into the vial headspace free (no air bubbles) and immediately cooled (4°C) for shipment. Multiple samples (usually about four taken from one large sample container) are taken because leakage of containers may cause losses, may allow air to enter the containers, and may cause erroneous analysis of some constituents. Also, some analyses are best conducted on independent protected samples.

7.6 The purgeable samples must be analyzed by the laboratory within 14 days after collection, unless they are to be analyzed for acrolein or acrylonitrile (in which case they are to be analyzed within 3 days). For samples for solvent extractions (extractable organics-base neutrals, acids and pesticides), the sample bottles are narrow mouth, screw cap quart bottles or half-gallon bottles that have been precleaned, rinsed with the extracting organic solvent and oven dried at 105°C for at least 1 h. These bottles must be sealed with TFE-fluorocarbon lined caps (Note). Samples for organic extraction must be extracted within 7 days and analyzed within 30 days after extraction. Special pre-cleaned, solvent rinsed and oven-dried stainless steel beakers (one for each monitoring well) may be used for transferring samples from the sampling device to the sample containers.

NOTE—When collecting samples, the bottles should not be overfilled or prerinsed with sample before filling because oil and other materials may remain in the bottle. This can cause erroneously high results.

7.7 For a number of groundwater parameters, the most meaningful measurements are those made in the field at the time of sample collection or at least at an on-site laboratory. These include the water level in the well and parameters that sometimes can change rapidly with storage. A discussion of the various techniques for measuring the water level in the well is contained in a NCASI publication (5) and detailed procedures are outlined in a U.S. Geological Survey publication (58). Although a discussion of these techniques is beyond the scope of this guide, it is important to point out that accurate measurements must be made before a well is flushed or only after it has had sufficient time to recover. Parameters that can change rapidly with storage include specific conductance, pH, turbidity, redox potential, dissolved oxygen, and temperature. For some of the other parameters, the emphasis in groundwater monitoring is on the concentration of each specific dissolved component, not the total concentration of each. Samples for these types of measurements should be filtered through 0.45 μm membrane filters ideally in the field or possibly at an on-site laboratory as soon as possible. Analyses often requiring filtered samples include all metals, radioactivity parameters, total organic carbon, dissolved orthophosphate (if needed), and total dissolved phosphorous (if needed) (13, 14). If metals are to be analyzed, filter the sample prior to acid preservation. For TOC organics, the filter material should be tested to assure that it does not contribute to the TOC. The type or size of the filter to be used is not well understood. However, if results of metal, TOC or other parameters that could be effected by solids are to be compared, the same filtering procedure must be used in each case. Repeated analytical results should state whether the samples were filtered and how they were filtered.

7.8 Shipment and receipt of samples must be coordinated with the laboratory to minimize time in transit. All samples for organic analysis (and many other parameters), should arrive at the laboratory within one day after it is shipped and be maintained at about 4°C with wet ice. The best way to get them to the laboratory in good condition is to send them in sturdy insulated ice chests (coolers) equipped with bottle dividers. 24-h courier service is recommended, if personal delivery service is not practical.

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APPENDIX D

Water Quality Analytical Protocol

APPENDIX D
WATER QUALITY ANALYTICAL PROTOCOL

Prior to the initiation of preproject groundwater sampling, a state of California-certified laboratory will be selected to conduct analytical testing. The laboratory will provide a copy of its QA/QC manual to Metropolitan's technical experts for review. The laboratory will be contracted contingent on acceptance of the QA/QC manual by Metropolitan's technical experts and Metropolitan. If necessary, an audit of the laboratory will be conducted.

In general, the selected laboratory will adhere to those recommendations promulgated in Title 21, Code of Federal Regulations, CFR Part 58 *Good Laboratory Practices*; criteria described in *Methods for Chemical Analysis of Water and Wastes* (EPA 1979; EPA-600/4-79-202); and requirements outlined in *Users Guide to the Contract Laboratory Program* (EPA, 1986). Groundwater samples collected for chemical analysis during this Project will be tested in accordance with the standard analytical procedures established by the EPA. The laboratory will be required to submit analytical results that are supported by sufficient backup data and QA/QC results to enable Metropolitan's technical experts to conclusively determine the validity of the data.

Analytical tests to be conducted during quarterly groundwater sampling events are summarized in Table D-1. The table summarizes each individual analyte to be tested, the appropriate EPA method number, and the proposed detection limit to be achieved.

General mineral constituents and physical parameters to be analyzed during baseline and annual spring water sampling events are summarized in Table D-2. The table summarizes each individual analyte to be tested, the appropriate EPA method number, and the proposed detection limit to be achieved.

Analytical tests to be conducted during annual Title 22 sampling of Colorado River Water are summarized in Table D-3. This table also summarizes each individual analyte to be tested, the appropriate EPA method number, and the proposed detection limit to be achieved.

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Quarterly Analytical Suite

General Classification	Constituent	Method	Detection Limit
Gen. Physical	Color	110.2	1
Gen. Physical	Odor	140.1	1
Gen. Physical	Turbidity	180.1	0.1
Gen. Mineral	pH	9040	0.01
Gen. Mineral	Bicarbonate	SM2320B	2
Gen. Mineral	Carbonate	SM2320B	2
Gen. Mineral	Alkalinity	310.1	2
Gen. Mineral	Hydroxide	SM2320B	2
Gen. Mineral	Hardness	130.2	1
Gen. Mineral	Total Dissolved Solids	160.1	10
Gen. Mineral	Surfactants (MBAS)	425.1	0.05
Gen. Mineral	Electrical Conductivity	120.1	1
Gen. Mineral	Chloride Cl^-	325.3	1
Gen. Mineral	Sulfate SO_4^{--}	375.4	2
Gen. Mineral	Nitrate as N	SM4500NO3D	1
Gen. Mineral	Calcium	6010	0.2
Gen. Mineral	Copper	6010	0.01
Gen. Mineral	Iron	6010	0.05
Gen. Mineral	Magnesium	6010	0.1
Gen. Mineral	Manganese	6010	0.005
Gen. Mineral	Potassium	6010	0.4
Gen. Mineral	Sodium	6010	2
Gen. Mineral	Zinc	6010	0.01
Other Inorganics	Arsenic	200.7	0.005
Other Inorganics	Bromide Br^-	320.1	0.02
Other Inorganics	Perchlorate		0.005

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Annual Spring Water Analytical Suite

General Classification	Constituent	Method	Detection Limit
Gen. Physical	Color	110.2	1
Gen. Physical	Odor	140.1	1
Gen. Physical	Turbidity	180.1	0.1
Gen. Mineral	pH	9040	0.01
Gen. Mineral	Bicarbonate	SM2320B	2
Gen. Mineral	Carbonate	SM2320B	2
Gen. Mineral	Alkalinity	310.1	2
Gen. Mineral	Hydroxide	SM2320B	2
Gen. Mineral	Hardness	130.2	1
Gen. Mineral	Total Dissolved Solids	160.1	10
Gen. Mineral	Surfactants (MBAS)	425.1	0.05
Gen. Mineral	Electrical Conductivity	120.1	1
Gen. Mineral	Chloride Cl^-	325.3	1
Gen. Mineral	Sulfate SO_4^{--}	375.4	2
Gen. Mineral	Nitrate as N	SM4500NO3D	1
Gen. Mineral	Calcium	6010	0.2
Gen. Mineral	Copper	6010	0.01
Gen. Mineral	Iron	6010	0.05
Gen. Mineral	Magnesium	6010	0.1
Gen. Mineral	Manganese	6010	0.005
Gen. Mineral	Potassium	6010	0.4
Gen. Mineral	Sodium	6010	2
Gen. Mineral	Zinc	6010	0.01
Chlorofluorocarbons	-	524.2	0.01
Tritium	-	*	1 pCi/L

Note: All concentrations are in milligrams per liter except where noted
* To be analyzed by LLNL

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

	Classification	Constituent	Units	Detection Limit	Method Number
Inorganics	General Physical Properties	Color	Standard unit	1	110.2
		Odor	Standard unit	1	140.1
		Turbidity	NTU	0.05	180.1
	General Minerals	Bicarbonate	mg/L	1	310.1
		Carbonate	mg/L	1	310.1
		Total Alkalinity	mg/L	1	310.1
		Calcium	mg/L	0.2	6010
		Chloride	mg/L	1	300
		Fluoride	mg/L	0.1	300
		Magnesium	mg/L	0.1	EPA 6010
		Nitrate (as N)	mg/L	0.4	300
		Nitrite (as N)	mg/L	0.4	300
		Total Nitrogen	mg/L	0.4	300
		pH	unit	N/A	150.1
		Potassium	mg/L	0.1	EPA 6010
		Sodium	mg/L	0.1	EPA 6010
		Sulfate	mg/L	0.5	300
		Specific Conductance	umhos/cm	1	120.1
		Total Dissolved Solids	mg/L	1	160.1
		Total Hardness	mg/L	1	130.2
	Other Inorganics	Perchlorate	µg/L	5	
		Cyanide	mg/L	0.05	335.2
		Bromide	mg/L	0.033	320.1
		Foaming Agents (MBAS)	µg/L	0.05	425.1
		Total Organic Carbon	mg/L	1	415.1
		Asbestos[8]	0.2 million fibers/L > 10µm		
		Ultra Violet 254	NS	NS	NS
	Metals	Aluminum	mg/L	0.01	200.8
		Antimony	mg/L	0.006	200.8
		Arsenic	mg/L	0.002	200.8
		Barium	mg/L	0.1	200.8
		Beryllium	mg/L	0.001	200.8
		Cadmium	mg/L	0.001	200.8

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

	Classification	Constituent	Units	Detection Limit	Method Number
	Metals (cont.)	Chromium	mg/L	0.01	200.8
		Copper	mg/L	0.01	200.8
		Iron	mg/L	0.01	200.8
		Lead	mg/L	0.005	200.8
		Manganese	mg/L	0.005	200.8
		Mercury	mg/L	0.001	200.8
		Nickel	mg/L	0.01	200.8
		Selenium	mg/L	0.005	200.8
		Silver	mg/L	0.01	200.8
		Thallium	mg/L	0.001	200.8
		Zinc	mg/L	0.05	200.8
	Radiological	Gross Alpha	pCi/L	1	NS
		Gross Beta	pCi/L	1	NS
		Radium 226	pCi/L	0.5	NS
		Radium 228	pCi/L	0.5	NS
		Radon 222	pCi/L	20	NS
		Strontium 90	pCi/L	1	NS
		Tritium	pCi/L	1	NS
		Uranium	pCi/L	1	NS
Organics	**Organochlorine Pesticides**	Alachlor	mg/L	0.001	507
		Aldrin	mg/L	0.00075	508
		Chlorothalonil	mg/L	0.005	508
		Dieldrin	mg/L	0.00002	508
		Endrin	mg/L	0.0001	508
		Lindane	mg/L	0.0002	508
		Methoxychlor	mg/L	0.01	508
		Toxaphene	mg/L	0.001	508
		Chlordane	mg/L	0.0001	508
		Heptachlor	mg/L	0.00001	508
		Heptachlor epoxide	mg/L	0.00001	508
		Propachlor	mg/L	0.0005	508
		Polychlorinated Biphenyls (PCBs)	mg/L	0.0005	508

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

Classification	Constituent	Units	Detection Limit	Method Number
Organochlorine Herbicides	2,4-D	mg/L	0.01	515.1
	2,4,5-TP Silvex	mg/L	0.001	515.1
	2,4,5-T	mg/L	NS	515.1
	Bentazon	mg/L	0.002	515.1
	Dalapon	mg/L	0.01	515.1
	Dicamba	mg/L	0.000081	515.1
	Dinoseb	mg/L	0.002	515.1
	Picloram	mg/L	0.001	515.1
	Pentachlorophenol	mg/L	0.0002	515.1
N-P Pesticides	Atrazine	mg/L	0.001	507
	Molinate	mg/L	0.002	507
	Simazine	mg/L	0.001	507
	Thiobencarb	mg/L	0.001	507
	Butachlor	mg/L	0.00038	507
	Diazinon	mg/L	0.00002	507
	Dimethoate	mg/L	0.01	507
	Malathion	mg/L	NS	507
	Prometryn	mg/L	0.02	507
	Bromacil	mg/L	0.01	507
	Metolachlor	mg/L	NS	507
	Metribuzin	mg/L	NS	507
Fumigants	Ethylene Dibromide (EDB)	mg/L	0.00002	504
	Dibromochloropropane (DBCP)	mg/L	0.00001	504
Carbamates	Diuron	mg/L	0.01	531
	Aldicarb	mg/L	0.03	531
	Aldicarb sulfone	mg/L	NS	531
	Aldicarb sulfoxide	mg/L	NS	531
	Oxamyl	mg/L	0.02	531
	Carbofuran	mg/L	0.005	531
	Carbaryl	mg/L	0.05	531
	3-Hydroxycarbofuran	mg/L	0.03	531
	Methomyl	mg/L	0.02	531
	Baygon (Propoxur)	mg/L	NS	531

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

Classification	Constituent	Units	Detection Limit	Method Number
Misc. Pesticides	Glyphosate	mg/L	0.025	547
	Endothail	mg/L	0.045	548
	Diquat & Paraquat	mg/L	0.004	549
	Polynuclear Aromatic Hydrocarbon	mg/L	NS	550
	2,3,7,8-TCDD Dioxin	mg/L	$5x10^{-9}$	
Semi-Volatile Organic Compounds	Benzo(a)pyrene	mg/L	0.0001	525
	Di(2-ethylhexyl)adipate	mg/L	0.005	525
	Di(2-ethylhexyl)phthalate	mg/L	0.003	525
	Hexachlorobenzene	mg/L	0.0005	525
	Hexachlorocyclopentadiene	mg/L	0.001	525
Volatile Organic Compounds	Benzene	mg/L	0.0005	524.2
	Carbon Tetrachloride	mg/L	0.0005	524.2
	1,2-Dichlorobenzene	mg/L	0.0005	524.2
	1,4-Dichlorobenzene	mg/L	0.0005	524.2
	1,1-Dichloroethane	mg/L	0.0005	524.2
	1,2-Dichloroethane	mg/L	0.0005	524.2
	cis-1,2-Dichloroethene	mg/L	0.0005	524.2
	trans-1,2-Dichloroethene	mg/L	0.0005	524.2
	1,1-Dichloroethene	mg/L	0.0005	524.2
	1,2-Dichloropropane	mg/L	0.0005	524.2
	1,3-Dichloropropene	mg/L	0.0005	524.2
	Ethylbenzene	mg/L	0.0005	524.2
	Methylene Chloride	mg/L	0.0005	524.2
	Methyl tert-butyl-ether (MTBE)	mg/L	0.0005	524.2
	Monochlorobenzene	mg/L	0.0005	524.2
	Styrene	mg/L	0.0005	524.2
	1,1,2,2-Tetrachloroethane	mg/L	0.0005	524.2
	Tetrachloroethene	mg/L	0.0005	524.2
	1,2,4-Trichlorobenzene	mg/L	0.0005	524.2
	1,1,1-Trichloroethane	mg/L	0.0005	524.2
	1,1,2-Trichloroethane	mg/L	0.0005	524.2
	Trichloroethene	mg/L	0.0005	524.2
	Trichlorofluoromethane	mg/L	0.005	524.2

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

Classification	Constituent	Units	Detection Limit	Method Number
Volatile Organic Compounds continued	1,1,2-Trichloro-1,2,2-trifluoroethane	mg/L	0.01	524.2
	Toluene	mg/L	0.0005	524.2
	Vinyl chloride	mg/L	0.0005	524.2
	Xylenes	mg/L	0.0005	524.2
	1,2-Dichlorobenzene	mg/L	0.0005	524.2
	Dibromomethane	mg/L	0.0005	524.2
	1,1-Dichloropropene	mg/L	0.0005	524.2
	1,3-Dichloropropane	mg/L	0.0005	524.2
	Chloromethane	mg/L	0.0005	524.2
	Bromomethane	mg/L	0.0005	524.2
	1,2,3-Trichloropropane	mg/L	NS	524.2
	1,1,1,2-Tetrachloroethane	mg/L	0.0005	524.2
	Chloroethane	mg/L	0.0005	524.2
	2,2-Dichloropropane	mg/L	0.0005	524.2
	o-Chlorotoluene	mg/L	0.0005	524.2
	p-Chlorotoluene	mg/L	0.0005	524.2
	Bromobenzene	mg/L	0.0005	524.2
	Dichlorodifluoromethane	mg/L	0.001	524.2
	1,2,4-Trimethylbenzene	mg/L	0.0005	524.2
	1,2,3-Trichlorobenzene	mg/L	0.0005	524.2
	n-Propylbenzene	mg/L	0.0005	524.2
	n-Butylbenzene	mg/L	0.0005	524.2
	Naphthalene	mg/L	NS	524.2
	Hexachlorobutadiene	mg/L	0.0005	524.2
	1,3,5-Trimethylbenzene	mg/L	0.0005	524.2
	p-Isopropyltoluene	mg/L	0.0005	524.2
	Isopropyltoluene	mg/L	0.0005	524.2
	Tert-butylbenzene	mg/L	0.0005	524.2
	Sec-butylbenzene	mg/L	0.0005	524.2
	Bromochloromethane	mg/L	0.0005	524.2
	Bromodichloromethane	mg/L	0.0005	524.2
	Bromoform	mg/L	0.0005	524.2
	Chlorodibromomethane	mg/L	0.0005	524.2
	Chloroform			

Metropolitan Water District of Southern California/Cadiz Inc.
Cadiz Groundwater Storage and Dry-Year Supply Project
Proposed Title 22 Analytical Suite

Classification	Constituent	Units	Detection Limit	Method Number
Microbiological Compounds	Heterotrophic Plate Count	CFU/ml	NS	SM9215B
	Total Coliforms	MPN/100 ml	NS	SM9221B
	Fecal Coliforms	MPN/100 ml	NS	SM9221C
	Cryptosporidium	NS	NS	EPA 1622
	Giardia	NS	NS	EPA 1623
	Enteric Viruses	NS	NS	EPA 1624

N/A - Not applicable

NS - Not specified in MWD analyte list or GEOSCIENCE laboratory analyte lists

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
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DRINKING WATER STANDARDS AND HEALTH ADVISORIES TABLE

DECEMBER 1995

Contact: Bruce Macler, Regional Toxicologist, (415) 744-1884
Drinking Water Branch, Water Management Division

REGION 9 DRINKING WATER STANDARDS AND HEALTH ADVISORIES TABLE

The USEPA Region 9 Drinking Water Standards and Health Advisories Table is a compendium of standards, health advisories and related information for chemicals and other contaminants which may be found in ground and surface waters. It provides a comprehensive listing of all current and proposed National Primary Drinking Water Regulations (NPDWRs), Maximum Contaminant Levels (MCLs) for California, Arizona and Hawaii, and California Drinking Water Action Levels. Where available, it includes USEPA Integrated Risk Information System (IRIS) cancer risk levels and oral reference dose (RfD) values, and USEPA Office of Ground Water and Drinking Water (OGWDW) Health Advisories for drinking water contaminants.

In order to make this table a manageable size, very few explanations or caveats for the values are included in the body of the table. Because of this, and the fact that background documentation and understanding of the derivation of specific values are critical to the proper use of this information, this table should not be used as a sole source of information for decision making. While the Appendix contains brief explanations of the different standards, criteria and advisories, consideration must be given to the context in which these numbers will be used. The appropriate reference materials should be consulted to determine the applicability of the number being considered. Some references are listed in the Appendix.

The values in this table are current to the publication date, but are subject to change. The user is advised to contact Bruce Macler, Regional Toxicologist, USEPA Region 9, at (415) 744-1884, if questions arise regarding current values.

INFORMATION IN THIS TABLE

The information for specific contaminants in this table is arranged by contaminant type. Inorganic chemicals are listed first, followed by radionuclides, organic chemicals, microbial contaminants and water quality factors.

For each contaminant, any applicable or proposed USEPA National Primary Drinking Water Regulation is listed. These include the enforceable **Maximum Contaminant Levels (MCLs)**, the health-based **Maximum Contaminant Level Goals (MCLGs)**, and the aesthetics-based **Secondary MCLs**. A given contaminant may have both a MCL and a Secondary MCL, as well as a MCLG. The regulatory status of these values is indicated. **Proposed MCLs or MCLGs** have been formally proposed by USEPA, but not promulgated. **Final MCLs or MCLGs** have been promulgated, but are not yet effective as of the publication date. The effective date, if available, is indicated. **Current MCLs or MCLGs** are in effect.

In addition to regulatory information, health risk information is provided in the table. Data from IRIS for cancer and non-cancer health effects associated with drinking water contaminants is listed. The **RfD** is the daily oral intake (on a body weight basis) that is below the level USEPA believes to be without adverse, non-cancer health risks (i.e., zero risk). The IRIS **10^{-6} risk level** is that contaminant concentration (in ug/liter) in drinking water that would yield no greater than an additional risk of one-in-a-million (10^{-6}) after a lifetime of drinking that water. The USEPA OGWDW Health Advisories provide information on acceptably safe levels of exposures to contaminants in drinking water. The **Acute 10-day** values apply specifically to acute toxic effects on children, but should be protective for adults. The **chronic (lifetime)** values for non-cancer health effects should be protective of health even with a lifetime exposure. For non-carcinogenic chemicals, this value is typically the same as the MCLG, if one has been established. The chronic (lifetime) values for cancer are set at a level that should yield no greater than an additional 10^{-6} risk over a lifetime exposure. EPA **cancer weight of evidence** determinations are listed to provide additional information on EPA's judgement of carcinogenicity for each chemical. The weight of evidence classifications are as follows:

A	known human carcinogen
B1	probable human carcinogen based on human data
B2	probable human carcinogen based on animal data
C	possible human carcinogen based on animal data
D	insufficient data to classify chemical
E	not a human carcinogen

APPLICABILITY AND USES OF THIS TABLE

The different types of standards and advisories contained in this table are based upon approaches and assumptions that are specific to each and consequently may have varying applications depending on their derivation. Use of specific types of information should be guided by the relevant legal requirements and an understanding of the meaning of the information itself.

MCLs and treatment techniques are the only federally enforceable NPDWRs. They are set to be health protective as well as feasible, and take into account analytical and treatment limitations. More stringent state-specific MCLs are enforceable in the indicated state. MCLGs, based solely on health information, are not enforceable, but provide health-based guidance for decision making. MCLGs for chemicals causing non-carcinogenic health effects are based on the RfD and set at a level believed to be safe. MCLGs for chemicals believed to be carcinogens are set at zero, from the perspective that no level of carcinogen is safe. Feasibility is not considered in setting MCLGs. Secondary MCLs are not enforceable, but provide information on aesthetics and palatability.

Health advisories and criteria are not formally promulgated in regulations and are subject to change as new data and analyses become available. MCLGs, values in IRIS and health advisories are developed by different offices and on different schedules. Therefore, values for similar effects from a given chemical may not be consistent throughout the table. The derivations of MCLGs and chronic (lifetime) health advisories for non-carcinogenic chemicals are based on the same assumptions regarding endpoints of toxicity. Slight differences in the table are due to rounding of numbers by different offices.

When considering a value to use for determining an acceptable level of contaminant in drinking water, the MCL should be selected first. In the absence of existing or proposed MCLs, users may have to decide which criteria are most appropriate. USEPA recommends a priority ranking to first consider any proposed MCLG (if other than zero), followed by the IRIS RfD or cancer risk level, and finally the chronic health advisory values.

Under the **Superfund Program**, remdial actions must comply with the **Applicable or Relevant and Appropriate Requirements (ARARs)**. For actions involving contamination of drinking water supplies, the ARARs under the Safe Drinking Water Act are the MCLs. Where there are no MCLs, or where the MCLs are determined to be insufficiently protective because of multiple contaminants, reference should be made to Superfund guidance documents to determine clean-up policy. For remedial actions impacting aquatic organisms and waters regulated under the Clean Water Act, consult the National Ambient Water Quality Criteria (NAWQC).

FDA STANDARDS FOR BOTTLED WATER

The U.S. Food and Drug Administration is responsible for regulating bottle water quality. It is required to adopt health-protective allowable limits for bottled water based on NPDWRs. FDA has adopted these MCLs:

Barium	Dibromochloropropane	o-Dichlorobenzene
Cadmium	2,4-D	p-Dichlorobenzene
Chromium	Ethylene dibromide	cis 1,2-Dichloroethylene
Mercury	Heptachlor	trans1,2-Dichloroethylene
Nitrate	Heptachlor epoxide	1,2-Dichloropropane
Nitrite	Lindane	Ethylbenzene
Selenium	Methoxychlor	Monochlorobenzene
Alachlor	Pentachlorophenol	Styrene
Atrazine	PCBs	Tetrachloroethylene
Carbofuran	Toxaphene	Toluene
Chlordane	2,4,5-TP (Silvex)	Xylenes

Allowable limits based on Secondary MCLs apply for aluminum and silver. In addition, bottled water must not exceed 5 ug/L lead and 1 mg/L copper.

SYMBOLS USED IN THE TABLE

mg/l = milligrams per liter, equivalent to parts per million **(ppm)**
ug/l = micrograms per liter, equivalent to parts per billion (ppb)

Note: values in table are in ug/l unless otherwise stated

IRIS = USEPA Integrated Risk Information System
RfD = Reference dose for daily oral ingestion in micrograms per kilogram body weight per day (ug/kg-d)
10^{-6} = one in a million excess lifetime cancer risk
TT = treatment technique, set in lieu of numeric MCL
\+ = value from USEPA Final Draft Health Advisory
td = temperature dependent value
LOQ = Limit of quantification
T&O = taste and odor refers to a value based upon organoleptic data for controlling undersirable taste and odor qualities

Drinking Water Standards And Health Advisories

INORGANIC		EPA		IRIS		Health Advisories			Wt.	California		
						Acute	Chronic(lifetime)		of			
Chemicals	Standard	MCL	MCLG	RfD µg/kg-d	10^{-6} Risk	10 Day	Non-Cancer	Cancer	Evid.	MCL	Action Level	Arizona MCL
Aluminum	Secondry	50-200								1000 200 Scd		
Ammonia							30,000		D			
Antimony	Current	6	6	0.4		15	3		D	6		
Arsenic	Current	50		0.3	0.02			0.02	A	50		50
Asbestos	Current	7E+6 10um fibers	7E+6 10um fibers						A	7E+6 fibers		
Barium	Current	2,000	2,000	70			2,000+		D	1,000		1000
Beryllium	Current	4	4	5	.008	30,000		0.008	B2	4		
Boron				90		900	600		D		1000	
Bromate	Proposed	10	0		0.05				B2			
Cadmium	Current	5	5	.5		40+	5+		D	5		10
Chloramines	Proposed	MRDL* 4.0mg/L as Cl2	MRDLG* 4 mg/L as Cl2	100		1000	3000- 4000		D			
Chlorate									D			
Chloride	Secondry	250mg/L								250-600 Secondr		
Chlorine	Proposed	MRDL* 4.0mg/L as Cl2	MRDLG* 4 mg/L as Cl2	80					D			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
* - MRDL, MRDLG: Maximum residual disinfectant level and goal. Apply only if this disinfectant is used.

INORGANIC		EPA		IRIS		Health Advisories			Wt.	California		
				RfD	10^{-6}	Acute	Chronic(lifetime)		of		Action	Arizona
Chemicals	Standard	MCL	MCLG	µg/kg-d	Risk	10 Day	Non-Cancer	Cancer	Evid.	MCL	Level	MCL
hlorine Dioxide	Proposed	MRDL* 0.8mg/L as ClO2	MRDLG* 0.3mg/L as ClO2	10			300		D			
hlorite	Proposed	1.0mg/L	80	3			80		D			
hromium(Total)	Current	100	100	5		1,000+	100+		D	50		50
opper	Current Secondry	TT## 1,000	1,300						D	1000 Secondr		
anide	Current	200	200	22		200+	200+		D	200		
luoride	Current Proposed secondry	4 mg/L 2 mg/L	4 mg/L	120						1400-2400td		
ron	Secondry	300								300 Secondr		
ead	Current	TT#	0						B2	50		
anganese	Secondry	50		140 (food) 5 (water)						50 Scd		
ercury inorganic)	Current	2	2	0.3			2+		D	2		
olybdenum				5		40	40		D			
ickel				20		1,000+	100+		D	100		
itrate (as N)	Current	10mg/L	10mg/L	1.6mg/L		10 mg/L***			D	45 mg/L as NO3		10mg/L (as N)
itrite (as N)	Current	1 mg/L	1 mg/L	160		1 mg/L***			D	1 mg/L		

alues are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

ral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
* - Treatment technique in lieu of numeric MCL
# - Treatment technique triggered at Action Level of 1300 ppb
a - td- temperature dependent value
- Treatment technique and public notification triggered at Action Level of 15 ppb
*** - 10-day HA for nitrate/nitrite for 4kg child (protective of 10kg child & adults); also used for chronic (lifetime)

INORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Selenium	Current	50	50	5						50		50
Silver	Secondry	100		5		200	100		D	100 Scd		50
Strontium				600		25 mg/L	17 mg/L		D			
Sulfate	Secondry Proposed	250mg/L 400/500 mg/L	 400/500 mg/L							250-600 Secondr		
Thalium	Current	2	0.5	0.07		7	0.4			2		
Vanadium				7					D			
White Phosphorous				.02			0.1		D			
Zinc	Secondry	5 mg/L		300		6 mg/L	2 mg/L		D	5 mg/L Secondr		5 mg/L
RADIONUCLIDES												
Gross Alpha, excl. Uranium & Radon	Current	15pCi/L						.15pCi/L	A	15pCi/L		
Gross Beta	Current	4mrem per yr						0.04mrem per year	A	50pCi/L		
Radium 226	Current Proposed	5 pCi/L (+228) 20pCi/L	 0					.20 pCi/L	A	5 pCi/L (+Ra 22		
Radium 228	Current Proposed	5 pCi/L (+226) 20pCi/L	 0					.20 pCi/L	A	5 pCi/L (+Ra 22		
Radon	Proposed	300 pCi/L	0					1.5pCi/L	A			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

RADIONUCLIDES Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Strontium 90									A	8pCi/L		
Tritium									A	20nCi/L		
Uranium	Proposed	20 ppb	0	3				0.7 ppb	A	20pCi/L		35pCi/l
ORGANIC												
Acenaphthylene (acenapthene)				60								
Acephate				4					C			
Acetone				100					D			
Acetophenone				100								
Acifluorfen				13	1.0	2,000+		1.0+	B2			
Acrolein									C			320
Acrylamide	Current	TT	0	1.0	.01	200		0.01+	B2			
Acrylonitrile					0.06	20+		0.06+	B1			10
Adipates (di(ethylhexyl)-adipate)	Current	400	400	600	30	20,000	400	30	C			
Alachlor	Current	2	0	10	0.4	100+		0.4+	B2	2		0.2

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
TT - Treatment technique in lieu of numeric MCL
a - Effective date postponed

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Aldicarb	Final(a)	3	1	1.0			7+		D		10	9
Aldicarb Sulfone	Final(a)	2	1	1.0			7+		D			
Aldicarb Sulfoxide	Final(a)	4	1	1.0			7+		D			
Aldrin				0.03	.002	0.3		0.002	B2		LOQ (0.05)	
Allyl alcohol				5								
Ametryn				9		9,000+	60+		D			
Ammonium Sulfamate				280		20,000+	2,000+		D			
Anthracene (PAH)				300					D			
Atrazine	Current	3	3	35	0.16	100+	3+		C	3		(HI 3)
Baygon (Propoxur)				4		40+	3+		C		90	
Benefin				300								
Bentazon (Basagran)				2.5		300+	20+		D	18		
Benz(a)anthracene (PAH)	Proposed	0.1	0						B2			
Benzene	Current	5	0		1	200+		1.0+	A	1		5

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Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
a - Effective date postponed
HI - State of Hawaii MCL

ORGANIC Chemicals	EPA Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic (lifetime) Non-Cancer	Health Advisories Chronic (lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Benzene hexachloride α, β isomers (BHC)											0.7 α 0.3 β	
Benzo(a)pyrene (PAH)	Current	0.2	0					.002	B2	0.2		
Benzo(b)fluoranthene (PAH)	Proposed	0.2	0						B2			
Bolero (thiobencarb)				20						70 1 Scd		
Bromacil				130		5,000+	90+		C			
Bromochloromethane				13		1,000	90					
Bromodichloromethane (TTHM)	Current Proposed	100 a 80 a	 0	20	0.6	7,000+		0.6	B2			
Bromoform (TTHM)	Current Proposed	100 a 80 a	 0	20	4	2,000		4	B2			
Bromomethane (Methyl Bromide)				1		100+	10+		D			2.5
Butyl benzyl-phthalate (PAE)	Proposed	100	0	200					C			
Butylate				50		2,000+	350+		D			
Captafol				2	4				C			
Captan				130					B2		350	
Carbaryl (Sevin)				100		1,000+	700+		D		60	

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.
a - See Trihalomethanes

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Carbofuran	Current	40	40	5		50+	40+		E	18		36
Carbon Disulfide				100								830
Carbon Tetrachloride	Current	5	0	0.7	0.3	200+		0.3+	B2	0.5		5
Carboxin				100		1,000+	700+		D			
Chloral Hydrate (Trichloroacet-aldehyde, CH)	Proposed	**	40	1.6	0.4	1,400	60		C			
Chloramben				15		3,000+	100+		D			
Chlordane	Current	2	0	0.06	0.03	60+		0.03+	B2	0.1		
Chlorobenzene (Monochlorobenzene)	Current	100	100	20		2,000+	100+		D	70		
Chlorodibromomethane (Dibromochloro-methane, TTHM)	Current Proposed	100 a 80 a	60	20		7,000	60		C			
Chloroform (trichloromethane) (TTHM)	Current Proposed	100 a 80 a	0	10	6	4,000		6.0	B2			
bis-2-Chloroiso-propyl ether				40		4,000+	300+		D			
Chloromethane				4		400	3		C			
2-Chlorophenol				5		50	40		D			
Chloropicrin											50(37 T&O)	

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
** - No chloral hydrate MCL. MCLs for TTHMs and THAAs, precusor removal as control.
a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.
a - See Trihalomethanes

ORGANIC Chemicals	EPA Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Chlorothalonil				15	1.5	200+		1.5+	B2			
Chlorotoluene(o,p)				20		2,000+	100+		D		45	
Chlorpyrifos				3		30+	20+		D			
CIPC (Chlorpropham) (isopropylN(3chloro-phenyl) carbamate)				200							350	
Cresol(o,m)				500					C			
Cresol(p)				5					C			
Cyanazine				2		100+	1		C			
Dalapon	Current	200	200	26		3,000+	200+		D	200		
DCPA (Dacthal)				500		80,000+	4,000+		D			
DDT				0.5	0.1				B2			
Di(ethylhexyl)-adipate (Adipates)	Current	400	400	600	30	20,000	400+	30	C	400		
Diazinon				0.09		20+	0.6+		E		14	
Dibromoacetonitrile				20		2000	20		C			
Dibromochloromethane (Chlorodibromo-methane, TTHM)	Current Proposed	100 a 80 a	60	20		7,000	60		C			

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Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.

- See Trihalomethanes

! - State of Hawaii MCL

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(Lifetime) Non-Cancer	Health Advisories Chronic(Lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
1,2-Dibromo-3-chloro propane (DBCP)	Current	0.2	0		0.03	50+		0.03	B2	0.2		(HI.04)
Dibutyl phthalate (PAE)				100					D			
Dicamba				30		300+	200+		D			
Dichloroacetic Acid (HAA5, THAA)	Proposed	60 ꝏ	0	4		1000			B2			
Dichloroacetonitrile				8		1000+	6+		C			
1,2-Dichlorobenzene (o-Dichlorobenzene)	Current Proposed secondry	600 10	600	90		9,000+	600+		D	600	130 *** (10T&O)	
1,3-Dichlorobenzene (m-Dichlorobenzene)				90		9,000+	600+		D		130 *** (20T&O)	
1,4-Dichlorobenzene (p-Dichlorobenzene)	Current Proposed secondry	75 5	75	100		10,000+	75+		C	5		750
Dichlorodifluoro-methane (Freon 12)				200		40,000+	1,000+		D		1000	1.0
1,1-Dichloroethane										5		
1,2-Dichloroethane	Current	5	0		0.4	700+		0.4	B2	0.5		5.0
1,1-Dichloroethylene	Current	7	7	9		1,000+	7+		C	6		7.0
cis-1,2-Dichloro-ethylene	Current	70	70	10		3,000+	70+		D	6		
trans-1,2-Dichloro-ethylene	Current	100	100	20		2,000+	100+		D	10		

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Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
ꝏ - See Haloacetic acids
ꝏ - Haloacetic acids (5) MCL is sum of mono-, di- and trichloroacetic acids and mono- and dibromoacetic acids.
*** - Action Level is for a single isomer or sum isomers

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Dichloromethane (Methylene chloride)	Current	5	0	60		2,000+		5+	B2	5		
2,4-Dichlorophenol				3		30+	20+		D			
2,4-Dichlorophenoxy -acetic acid (2,4-D)	Current	70	70	10		300+	70+		D	100		100
1,2-Dichloropropane	Current	5	0		0.5	90+		0.6+	B2	5		
1,3-Dichloropropene				0.3	0.2	30+		0.2+	B2	0.5		
Dieldrin				0.05	.002	0.5+		0.002+	B2		.05	
Diethylphthalate (PAE)				800			5000+		D			
Diisopropylmethyl-phosphonate				80		8,000+	600+		D			
Dimethoate				0.2							140	
Dimethrin				300		10,000+	2,000+		D			
Dimethylaniline				20	0.05				C			
Dimethyl methyl-phosphonate				200	7	2000	100	7	C			
2,4-Dimethylphenol				200							400	
1,3 Dinitrobenzene				0.1		40	1		D			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
tg - technical grade dinitrotoluene only

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
2,4-Dinitrotoluene				2	.05 (tg)	500		.05 (tg)	B2 (TG)			
2,6-Dinitrotoluene				1.0	.05 (tg)	400		.05 (tg)	B2 (TG)			
Dinoseb	Current	7	7	1		300+	7+		D	7		
1,4-Dioxane (p-Dioxane)					7	400+		7+	B2			
Dioxin (2,3,7,8-TCDD)	Current	3E-5	0	1E-6	2E-7	1E-4		2E-7+	B2	3E-5		
Diphenamid(e)				30		300+	200+		D		40	
Diphenylamine				30		1000	200		D			
Di(ethylhexyl)-phthalate (PAE) (Phthalates)	Current	6	0	20	3			3+	B2	4		
Diquat	Current	20	20	2.2			20+		D	20		
Disulfoton				0.04		10+	0.3+		E			
1,4-Dithiane				10		400	80		D			
Diuron				2		1,000+	10+		D			
Endothall	Current	100	100	20		800+	100+		D	100		
Endrin	Current	2	2	0.3		20+	2+		D	2		0.2

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
tg - technical grade dinitrotoluene only
TT - Treatment technique in lieu of numeric MCL

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Chronic(lifetime) Non-Cancer	Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Epichlorohydrin	Current	TT	0	2	4	100+		4	B2			
Ethion				0.5							35	
Ethylbenzene	Current Proposed secondry	700 30	700	100		3,000+	700+		D	700		
Ethylene Dibromide (dibromoethane) (EDB)	Current	0.05	0		4E-4	8		0.0004	B2	0.05		(HI.04)
Ethylene Glycol				2,000		6,000+	7,000+		D			
Ethylene Thiourea (ETU)				0.08	0.3	300+		0.3	B2			
Fenamiphos				0.25		9+	2+		D			
Fluometuron				13		2,000+	90+		D			
Fluorotrichloro-methane				300		7,000+	2,000+		D			
olpet				100					B2			
Fonofos				2		20+	10+		D			
Formaldehyde				150		5,000+	1,000+		B1		30	
Glycidaldehyde				4					B2			
Glyphosate	Current	700	700	100		20,000+	700+		D	700		

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Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
HI - State of Hawaii MCL
HA - Haloacetic acids (5) MCL is sum of mono-, di- and trichloroacetic acids and mono- and dibromoacetic acids.

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Haloacetic acids (5) (HAA5, THAAs)	Proposed	60 ~~aa~~										
Heptachlor	Current	0.4	0	0.5	.008	10+		0.008+	B2	0.01		
Heptachlor epoxide	Current	0.2	0	0.013	.004			0.004	B2	0.01		
Hexachlorobenzene (Perchlorobenzene) (HCB)	Current	1	0	0.8	0.02	50+		0.02+	B2	1		
Hexachlorobutadiene				2		300+	1+		C			
Hexachlorocyclo-pentadiene (HEX)	Current Proposed secondary	50 8	50	7					D	50		
n-Hexane						4,000+			D			
Hexazinone				33		3,000+	200+		D			
HMX				50		5,000+	400+		D			
Isophorone				200		15,000+	100+	40	C			
Lindane (gamma-HCCH) (gamma-BHC)	Current	0.2	0.2	0.3		1,000+	0.2+	0.03	C	0.2		
Linuron				2					C			
Malathion				20		200+	200+		D		160	
Maleic Hydrazide				500		10,000+	4,000+		D			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
MCPA				1.5		100+	11+		E			
Merphos				0.03								
Methomyl (Lannate)				25		300+	200+		D			
Methoxychlor	Current	40	40	5		50	40		D	40		
Methylene Chloride (Dichloromethane)	Current	5	0	60	5	2,000+		5+	B2		40	
Methyl ethyl ketone (MEK,2-Butanone)				600					D			
Methyl Parathion				.25		300+	2+		D		30	
Methyl t-butyl ether				30		24,000	200		C		35	
Metolachlor				150		2,000+	100+		C			
Metribuzin				13		5,000	100		D			
Mirex				0.2	.02				B2			
Molinate				2						20		
Naphthalene				4		500+	20+		D			
Nitroguanidine				100		10,000+	700+		D			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

ORGANIC Chemicals	EPA Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(Lifetime) Non-Cancer	Health Advisories Chronic(Lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Oxamyl (Vydate)	Current	200	200	25		200+	200+		E	200		
Paraquat				4.5		100+	30+		E			
Parathion (Ethyl Parathion)				6					C		30	
Pentachloronitro-benzene (Terracnlor)				3	0.1				C		0.9	
Pentachloropnenol	Current	1	0	30	0.3	300+		0.3	B2	1	30	
Phenol				600		6,000+	4,000+		D		5(T&O) Cl2Syst	
Phthalates (di(ethylhexyl)-phthalate)	Current	6	0	20	3			3+	B2	4		
Picloram	Current	500	500	70		20,000+	500+		D	500		
Polychlorinated Biphenyls (PCBs)	Current	0.5	0		.005			0.005	B2	0.5		
Polynuclear Aromatic Hydrocarbons (PAHs) (benzo(a)pyrene)	Current	0.2	0						B2			
Prometon				15		200+	100+		D			
Pronamide				75		800+	50+		C			
Propachlor				13		500+	90+		D			
Propazine				20		1,000+	10+		C			

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

ORGANIC Chemicals	EPA Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Propham				20		5,000+	100+		D			
RDX				3	0.3	100+	2+	.3	C			
Simazine	Current	4	4	5		70	4+		C	4		
Styrene	Current Proposed secondry	100 10	100	200		2,000+	100+		C	100		
Tebutiuron				70		3,000+	500+		D			
Terbacil				13		300+	90+		E			
Terbufos				.13		5+	0.9+		D			
Terrachlor (pentachloro-nitrobenzene)				3	0.1				C		0.9	
1,1,1,2-Tetrachloro-ethane				30	1	2,000+	70+	1+	C			
1,1,2,2-Tetrachloro-ethane									C	1		
Tetrachloroethylene (Perchloroethylene)	Current	5	0	10	0.7	2,000+		0.7+	B2	5		
2,3,7,8-Tetrachloro-dibenzo-p-dioxin (Dioxin)	Current	3E-5	0	1E-6	2E-7	1E-4+		2E-7+	B2	3E-5		
Thiobencarb (Bolero)				20						70 1 Scd		
Toluene	Current Proposed secondry	1,000 40	1,000	200		2,000+	1,000+		D	150		

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.

ORGANIC Chemicals	EPA Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
Toxaphene	Current	3	0	100	0.03	40+		0.03+	B2	3		5
Tribromomethane (Bromoform, TTHM)	Current Proposed	100 a 80 a		20	4	2,000+		4	B2			
Trichloroacet-aldehyde (Chloral hydrate)	Proposed	**	40	1.6	0.4				C			
Trichloroacetic acid (HAA5, THAA)	Proposed	60 aa	300	100		4000	300		C			
1,2,4-Trichloro-benzene	Current	70	70	1		100+	70		D	70		
1,3,5-Trichloro-benzene				6		600+	40+		D			
1,1,1-Trichloro-ethane	Current	200	200	35		40,000+	200+		D	200		200
1,1,2-Trichloro-ethane	Current	5	3	4		400+	3+		C	5		
Trichloroethylene	Current	5	0		3			3	B2	5		5
Trichlorofluoro-methane (Freon 11)				700						150	150	
2,4,6-Trichloro-phenol					3			3	B2			
2,4,5,-Trichloro-phenoxyacetic acid (2,4,5-T)				10		800+	70+		D			
2,4,5 Trichlorophen-oxypropionic acid (2,4,5-TP) (Silvex)	Current	50	50	7.5		200+	50+		D	50		10
1,2,3-Trichloro-propane				6	5	600+	40+	5	B2			(HI .8)

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.
a - See Trihalomethanes
** - No chloral hydrate MCL. MCLs for TTHMs and THAAs, precusor removal as control.
aa - Haloacetic acids (5) MCL is sum of mono-, di- and trichloroacetic acids and mono- and dibromoacetic acids.
aa - See Haloacetic acids
HI - State of Hawaii MCL

ORGANIC Chemicals	Standard	EPA MCL	EPA MCLG	IRIS RfD µg/kg-d	IRIS 10^{-6} Risk	Health Advisories Acute 10 Day	Health Advisories Chronic(lifetime) Non-Cancer	Health Advisories Chronic(lifetime) Cancer	Wt. of Evid.	California MCL	California Action Level	Arizona MCL
1,1,2-Trichloro-1,2, 2-Trifluoroethane (Freon 113)										1200		
Trifluralin				7.5		80+	5+	5+	C			
Trihalomethanes (TTHM)	Current Proposed	100 a 80 a							B2	100		
Trinitroglycerol						5	5					
Trinitrotoluene				0.5	1	20	2	1	C			
Trithion											7	
Vinyl Chloride	Current	2	0		.015	3,000+		0.015+	A	0.5		
Xylenes- sum of isomers	Current Proposed secondry	10ppm 20	10ppm	2000		40,000+	10,000+		D	1750		
MICROB.-TURBIDITY												
Cryptosporidium	Proposed	TT	0									
Giardia Lamblia	Current	TT	.									
Heterotrophic Plate Count	Current	TT β	NA									
Legionella	Current	TT β	0									
Total Coliforms	Current	P/A aa	0									

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
a - Total Trihalomethanes MCL is sum of bromoform, chloroform, bromodichloromethane, dibromochloromethane.
TT - Treatment technique in lieu of numeric MCL
β - Surface waters and groundwater under the direct influence of surface water only.
aa - P/A - MCL is based on the presence/absence of total coliforms
γ - 0.5 NTU, conv. or direct filtration; 1.0 NTU, DE or slow sand filtration

MICROB.-TURBIDITY		EPA		IRIS		Health Advisories			Wt. of Evid.	California		Arizona
Chemicals	Standard	MCL	MCLG	RfD µg/kg-d	10^{-6} Risk	Acute 10 Day	Chronic(lifetime) Non-Cancer	Cancer		MCL	Action Level	MCL
Turbidity	Current	0.5 or 1.0 NTU a	NA									
Viruses	Current	TT β	0									

WATER QLTY.SECONDARY MAX.CONT.LEV

Chemicals	Standard	MCL	MCLG	RfD µg/kg-d	10^{-6} Risk	Acute 10 Day	Non-Cancer	Cancer	Wt. of Evid.	California MCL	Action Level	Arizona MCL
Color	Secondry	15color units										
Corrosivity	Secondry	Noncorrosive										
Foaming Agents	Secondry	500										
Odor (Odor threshold)	Secondry	3.0 OT#										
Total Dissolved Solids (TDS)	Secondry	500 ppm										
pH	Secondry	6.5-8.5										

Values are indicated in micro grams per liter (µg/l) [equivalent to parts per billion (ppb)] unless otherwise stated

Oral Referenced Doses (RfD) are in micrograms per kilogram per day (µg/kg-d), 10^{-6} risk levels are in micrograms per liter.
TT - Treatment technique in lieu of numeric MCL
β - Surface waters and groundwater under the direct influence of surface water only.
- Odor Threshold Numbers

TABLE 2

PRIORITY LIST OF CONTAMINANTS WHICH MAY REQUIRE REGULATION UNDER THE SDWA (1991 VERSION)

Microorganisms

Cryptosporidium

Inorganics

Aluminum
Boron
Chloramines
Chlorate
Chlorine
Chlorine dioxide
Chlorite
Cyanogen chloride
Hypochlorite ion
Manganese
Molybdenum
Strontium
Vanadium
Zinc

Pesticides

Asulan
Bentazon
Bromacil
Cyanazine
Cyromazine
DCPA (and acid metabolites)
Dicamba
Ethylenethiourea
Fomesafen
Latofen/Acifluorfen
Metalaxyl
Methomyl
Metolachlor
Metribuzin
Parathion degradation product (4-nitrophenol)
Prometon
2,4,5-T
Thiodicarb
Trifluralin

Synthetic Organic Chemicals

Acrylonitrile
Bromobenzene
Bromochloroacetonitrile
Bromodichloromethane
Bromoform
Bromomethane
Chloroethane
Chloroform
Chloromethane
Chloropicrin
o-Chlorotoluene
p-Chlorotoluene
Dibromoacetonitrile
Dibromochloromethane
Dibromomethane
Dichloroacetonitrile
1,3-Dichlorobenzene
Dichlorodifluoromethane
1,1-Dichloroethane
2,2-Dichloropropane
1,3-Dichloropropane
1,1-Dichloropropene
1,3-Dichloropropene
2,4-Dinitrophenol

Synthetic Organic Chemicals (con't)

2,4-Dinitrotoluene
2,6-Dinitrotoluene
1,2-Diphenylhydrazine
Fluorotrichloromethane
Hexachlorodutadiene
Hexachloroethane
Isophorone
Methyl ethyl ketone
Methyl isobutyl ketone
Methyl t-butyl ether
Naphthalene
Nitrobenzene
1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
Tetrahydrofuran
Trichloroacetonitrile
1,2,3-Trichloropropane

Chlorination/ chloramination byproducts (misc.): haloacetic acids, haloketones, chloral hydrate, 3-chloro-4-(dichloromethyl)-5-hydroxy-2(5H)-furanone (MX-2), N-organochloramines

Ozonation byproducts: aldehydes, epoxides, peroxides, nitrosamines, bromate, iodate

APPENDIX

DESCRIPTION OF STANDARDS AND ADVISORIES

Authority

Under the authority of the Safe Drinking Water Act (SDWA, Public Law 93-523), the USEPA is mandated to establish National Primary Drinking Water Regulations for contaminants occurring in drinking water. Primary NPDWRs are established and enforced to protect the public from adverse health effects resulting from a drinking water contaminant. Included in these regulations are the drinking water standards which set either 1) treatment techniques to control a contaminant, or 2) the Maximum Contaminant Level (MCL) allowable for the contaminant in drinking water. An MCL is set when an appropriate method of detection for the contaminant exists. A treatment technique approach is used when it is not possible to quantify the contaminant at the level necessary to protect public health. Secondary standards are established based on non-health related aesthetic qualities of appearance, taste and odor. These secondary standards are not federally enforceable.

States may choose to accept responsibility (Primacy Status) for the oversight and enforcement of US drinking water regulations. States which have primacy status from USEPA must adopt State drinking water standards that are at least as stringent as federal standards. A state may choose to enforce secondary standards as well as primary standards.

USEPA Maximum Contaminant Level Goals (MCLGs)

MCLGs are developed by the Office of Science and Technology in the USEPA Office of Water as a required first step toward promulgation of NPDWRs. MCLGs are non-enforceable health goals which are to be set at levels at which no known or anticipated adverse effects on the health of persons occur, and which allow for an adequate margin of safety. Prior to the SDWA Amendments of 1986, these levels were called Recommended Maximum Contaminant Levels (RMCLs). MCLGs are strictly health-based levels and are derived from relevant toxicological data.

For chemicals that produce adverse health effects and are not believed to be carcinogenic (non-carcinogens), the MCLG is based on the Reference Dose (RfD). A RfD is calculated from toxicological data to represent a contaminant level that should be without risk of adverse health effects even with a lifetime exposure. USEPA assumes that a threshold exists for non-cancer health effects from chemical contaminants, below which the effect will not occur. Thus the MCLG will be a non-zero number. The RfD, which is based on the total daily amount of contaminant taken up by a person on a body weight basis, is converted to a Drinking Water Equivalent Level (DWEL) concentration and adjusted for the percentage contribution of other sources (relative source contribution, RSC) of the contaminant besides drinking water (air, food, etc) to arrive at the MCLG. This calculation assumes a lifetime consumption of 2 liters of drinking water per day by a 70 kg adult. Unless otherwise noted, the RSC from drinking water for organic and inorganic compounds is respectively 20% and 10%.

USEPA assumes that no threshold exists for cancer and thus, there is no absolutely safe level of contamination. For chemicals that are known (Group A) or probable (Group B) human carcinogens, USEPA policy directs that the MCLG be set at zero, in accordance with a recommendation by the US Congress. For contaminants believed to be possible human carcinogens (Group C), the MCLG may be derived based on relevant non-cancer health effects as described above. In this case, the RfD is divided by an additional uncertainty factor of 10. In some cases, Group C chemicals will have MCLGs set based on calculated maximum lifetime cancer risks of between 1/10,000 and 1/million.

Maximum Contaminant Levels (MCLs)

MCLs are federally enforceable limits for contaminants in drinking water established as NPDWRs. The MCL for a given contaminant is set as close to the corresponding MCLG as is feasible. "Feasible" is defined in the 1986 SDWA Amendments as "feasible with the use of the best technology, treatment techniques and other means which the Administrator finds, after examination for efficacy under field conditions and not solely under laboratory conditions, are available (taking cost into consideration)." To promulgate a MCL for a contaminant requires that a method of detection for that contaminant is available suitable for the level desired and a Best Available Technology is identified that can feasibly remove the contaminant to the desired level.

Secondary Maximum Contaminant Levels

Secondary MCLs are established under the SDWA to protect the public welfare. Such regulations apply to contaminants in drinking water that adversely affect its odor, taste or appearance and consequently cause a substantial number of persons to discontinue its use. Secondary MCLs are not based on direct adverse health effects associated with the contaminant, although some contaminants may have both a MCL and a SMCL. SMCLs are considered as desirable goals and are not fereally enforceable. However, states may choose to promulgate and enforce SMCLs at the state level.

Health Advisories

Health Advisories (HAs) for drinking water contaminants are levels considered to be without appreciable health risk for specific durations of exposure. HAs should be considered guidance and are not enforceable drinking water standards. HAs were previously know as Suggested No Adverse Response Levels (SNARLs).

USEPA HAs are develcped and published initially as External Review Drafts, and then as a Final Draft. This designation indicates that the HA will be always subject to change as additional information becomes available. HAs are developed for one-day, 10-day, longer-term (approximately 7 years) and lifetime (70 year) exposures based on data describing non-carcinogenic health effects resulting from the contaminant. One-day and 10-day HAs use parameters which reflect exposures and effects for a 10 kg child consuming 1 liter of water per day. Lifetime HAs consider a 70 kg adult consuming 2 liters of water per day. Longer-term HAs can incorporate either child or adult parameters. A relative source contribution from water is also factored into the lifetime HA calculation to account for exposures from other sources (air, food, soil, etc) of the contaminant.

For known or probably human carcinogens, the lifetime HA level is based on an upper-bound excess lifetime cancer risk of 1/million. This means that **USEPA considers that the risk from a lifetime consumption of water at the given level is unlikely to be greater than 1/million, is most likely substantially less and may be zero.**

Reference Dose (RfD) and Drinking Water Equivalent Level (DWEL)

The RfD is a daily exposure level which is believed to be without appreciable health risk to humans over a lifetime. The RfD is usually derived from an experimental "no observed adverse effect level" (NOAEL), identified as the highest dose in the most relevant study that did not result in a known adverse effect. The NOAEL is divided by various uncertainty factors to derive the RfD. These uncertainty factors account for the variation in human response, extrapolation to human responses if animal experiments were used, data quality and relevance. The RfD takes the form of dose ingested per unit body weight per day (ug/kg-d).

The DWEL is the conversion of the RfD into an equivalen water concentration. It assumes that a 70 kg adult consumes two liters of water per day and that the total dose to a person results solely from drinking water. It is important to remember that actual exposures in the environment may occur through other routes, such as inhalation or dermal contact, or from other sources, such as from food or soil.

California Action Levels

California Department of Health Services Action Levels are health-based criteria derived much in the same way as EPA Health Advisories. Specific approaches to determining cancer risks and exposure assumptions may differ in some ways from those used by USEPA. California Action Levels are not enforceable drinking water standards, but are levels at which CA DOHS strongly urges water purveyors to take corrective action to reduce the level of contamination in the water they supply. Action Levels cease to exist when CA State MCLS are promulgated.

Integrated Risk Information System (IRIS)

IRIS is an EPA catalogue of Agency risk assessment and risk management information for chemical substances. It is available electronically in several formats. The risk assessment information contained in IRIS, unless specifically noted, has been reviewed and agreed upon by intra-agency work groups and represents Agency consensus. Chemical contaminants listed in IRIS may have descriptions of relevant toxicological experiments and risk assessment approaches used in the determination of RfDs, cancer risks and health advisories. Extensive bibliographies are included. Regulations and regulatory status for different media may be presented.

REFERENCES

EPA NPDWRs: Code of Federal Regulations, Title 40, Part 141

NPDWRs; Synthetic Organic Chemicals, Inorganic Chemicals and Microorganisms; Proposed Rule: FR 50, n. 219, November 13, 1985. (Phase I contaminants.)

NPDWRs; Volitile Synthetic Organic Chemicals, Final Rule and Proposed Rule: FR 50, n. 219, November 13, 1985. (Phase I chemicals.)

NPDWRs; Fluoride; Final Rule and Proposed Rule: FR 50, n. 220, November 14, 1985.

NPDWRs; Fluoride; Final Rule: FR 51, n. 63, April 2, 1986.

NPDWRs; Volatile Organic Chemicals; Final Rule: FR 52, n. 130, July 8, 1987. (Phase I chemicals.)

NPDWRs; Filtration and Disinfection; Turbidity, Giardia lamblia, Viruses, Legionella, and Heterotrophic Bacteria; Proposed Rule: FR 52, n. 212, November 3, 1987.

Drinking Water; NPDWRs; Total Coliforms; Proposed Rule: FR 52, n. 212, November 3, 1987.

Drinking Water Regulations; MCLGs and NPDWRs for Lead and Copper; Proposed Rule: FR 53, n. 160, August 18, 1988.

NPDWRs, Proposed Rule: FR 54, n. 97, May 22, 1989. (Phase II inorganics, VOCs, SOCs.)

Drinking Water; NPDWRs; Filtration, Disinfection; Turbidity, Giardia lamblia, Viruses, Legionella, and Heterotrophic Bacteria; Final Rule: FR 54, n. 124, June 29, 1989.

Drinking Water; NPDWRs; Total Coliforms (Including Fecal Coliforms and E. coli); Final Rule: FR 54, n. 124, June 29, 1989.

NPDWRs; Synthetic Organic Chemicals and Inorganic Chemicals; Proposed Rules: FR 55, n. 143, July 25, 1990. (Phase V chemicals.)

Priority List of Substances Which May Require Regulation Under the Safe Drinking Water Act; Notice: FR 56, n. 9, January 14, 1991.

NPDWRs, Final Rule: FR 56, n. 20, January 30, 1991. (Phase II inorganics, VOCs, SOCs.)

NPDWRs, Proposed Rule: FR 56, n. 20, January 30, 1991. (Aldicarb, Aldicarb Sulfoxide, Aldicarb Sulfone, Pentachlorophenol, Barium.)

MCLGs and NPDWRs for Lead and Copper; Final Rule: FR 56, n. 110, June 7, 1991.

NPDWRs; Final Rule: FR 56, n. 126, July 1, 1991. (Aldicarb, Aldicarb Sulfoxide, Aldicarb Sulfone, Pentachlorophenol, Barium.)

NPDWRs; Radionuclides; Proposed Rule: FR 56, n. 138, July 18, 1991.

NPDWRs; Synthetic Organic Chemicals and Inorganic Chemicals; Final Rule: FR 57, n. 138, July 17, 1992. (Phase V chemicals.)

NPDWRs; Disinfectants and Disinfection Byproducts; Proposed Rule: FR 59, n. 145, July 29, 1994.

NPDWRs; Enhanced Surface Water Treatment Requirements; Proposed Rule, FR 59, n. 145, July 29, 1994.

Drinking Water Standards

Primary Maximum Contaminant Levels (MCLs) and Lead and Copper Action Levels

Last Update: February 11, 2000

Primary MCLs
Lead and Copper

Primary maximum contaminant levels (MCLs) are established by the Department of Health Services (DHS) for a number of chemical and radioactive contaminants. Primary MCLs can be found in Title 22 California Code of Regulations (CCR) for

inorganic chemicals
(§64431),
trihalomethanes
(§64439),
radioactivity
(§64441 and §64443) and
organic chemicals
(§64444). (See DHS' compilation of drinking water statutes and regulations)

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
22 CCR §64431, Table 64431-A— Inorganic Chemicals	
Aluminum (Aluminum also as a secondary MCL of 0.2 mg/L)	1
Antimony	0.006
Arsenic	0.05
Asbestos (MFL = million fibers per liter, MCL is for fibers exceeding 10 microns in length)	7 MFL
Barium	1
Beryllium	0.004
Cadmium	0.005
Chromium	0.05
Cyanide	0.2
Fluoride	2
Mercury	0.002
Nickel	0.1
Nitrate (as NO_3)	45
Nitrate + Nitrite (sum as nitrogen)	10

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
Nitrite (as nitrogen)	1
Selenium	0.05
Thallium	0.002
22 CCR §64433.2, Table 64433.2-A, Optimal Fluoride Levels See also the Fluoride MCL, 22 CCR §64431, Table 64431-A	
Annual average of maximum daily air temperature (degrees Fahrenheit, °F)	**Optimal Level (Range)**
50.0 to 53.7 °F	1.2 (1.1-1.7)
53.8 to 58.3 °F	1.1 (1.0-1.6)
58.4 to 63.8 °F	1.0 (0.9-1.5)
63.9 to 70.6 °F	0.9 (0.8-1.4)
70.7 to 79.2 °F	0.8 (0.7-1.3)
79.3 to 90.5 °F	0.7 (0.6-1.2)
22 CCR §64441 and §64443— Radioactivity	
Gross alpha particle activity (including radium-226 but excluding radon and uranium)	15 picocuries per liter (pCi/L)
Gross beta particle activity	50 pCi/L

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
Combined Radium-226 and Radium-228	5 pCi/L
Strontium-90	8 pCi/L
Tritium	20,000 pCi/L
Uranium	20 pCi/L
22 CCR §64439— Total Trihalomethanes	
Sum of bromodichloromethane, dibromochloromethane, bromoform, and chloroform	0.1
22 CCR §64444— Organic Chemicals	
(a) Volatile Organic Chemicals (VOCs)	
Benzene	0.001
Carbon tetrachloride	0.0005
1,2-Dichlorobenzene (o-Dichlorobenzene)	0.6
1,4-Dichlorobenzene (p-DCB)	0.005
1,1-Dichloroethane (1,1-DCA)	0.005
1,2-Dichloroethane (1,2-DCA)	0.0005
1,1-Dichloroethylene (1,1-DCE)	0.006

PRIMARY MAXIMUM CONTAMINANT LEVELS

All values are in milligrams per liter (mg/L), unless otherwise noted

Contaminant	Primary MCL
cis-1,2-Dichloroethylene	0.006
trans-1,2-Dichloroethylene	0.01
Dichloromethane (Methylene chloride)	0.005
1,2-Dichloropropane (Propylene dichloride)	0.005
1,3-Dichloropropene	0.0005
Ethylbenzene (Phenylethane)	0.7
Monochlorobenzene (Chlorobenzene)	0.07
Methyl tert-Butyl Ether (MTBE) (MTBE also has a secondary MCL of 0.005 mg/L and an action level of 0.013 mg/L)	0.013 (proposed)
Styrene (Vinylbenzene)	0.1
1,1,2,2-Tetrachloroethane	0.001
Tetrachloroethylene (PCE)	0.005
Toluene (Methylbenzene)	0.15
1,2,4-Trichlorobenzene (Unsym-Trichlorobenzene)	0.07
1,1,1-Trichloroethane (1,1,1-TCA)	0.2
1,1,2-Trichloroethane (1,1,2-TCA)	0.005

PRIMARY MAXIMUM CONTAMINANT LEVELS

All values are in milligrams per liter (mg/L), unless otherwise noted

Contaminant	Primary MCL
Trichloroethylene (TCE)	0.005
Trichlorofluoromethane (Freon 11)	0.15
1,1,2-Trichloro-1,2,2-Trifluoroethane (Freon 113)	1.2
Vinyl chloride	0.0005
Xylenes (single isomer or sum of isomers)	1.75
(b) Non-Volatile Synthetic Organic Chemicals (SOCs)	
Alachlor (Alanex)	0.002
Atrazine (Aatrex)	0.003
Bentazon (Basagran)	0.018
Benzo(a)pyrene	0.0002
Carbofuran (Furadan)	0.018
Chlordane	0.0001
2,4-D	0.07
Dalapon	0.2
1,2-Dibromo-3-chloropropane (DBCP)	0.0002
Di(2-ethylhexyl)adipate	0.4

PRIMARY MAXIMUM CONTAMINANT LEVELS

All values are in milligrams per liter (mg/L), unless otherwise noted

Contaminant	Primary MCL
Di(2-ethylhexyl)phthalate (DEHP)	0.004
Dinoseb	0.007
Diquat	0.02
Endrin	0.002
Endothal	0.1
Ethylene dibromide (EDB)	0.00005
Glyphosate	0.7
Heptachlor	0.00001
Heptachlor epoxide	0.00001
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05
Lindane (gamma-BHC)	0.0002
Methoxychlor	0.04
Molinate (Ordam)	0.02
Oxamyl	0.2

PRIMARY MAXIMUM CONTAMINANT LEVELS	
All values are in milligrams per liter (mg/L), unless otherwise noted	
Contaminant	**Primary MCL**
Pentachlorophenol	0.001
Picloram	0.5
Polychlorinated biphenyls (PCBs)	0.0005
Simazine (Princep)	0.004
2,4,5-TP (Silvex)	0.05
2,3,7,8-TCDD (Dioxin)	0.00000003
Thiobencarb (Bolero) (Thiobencarb also has a secondary MCL of 0.001 mg/L)	0.07
Toxaphene	0.003

Lead and copper
have specific regulations in 22 CCR, Chapter 17.5 §64670, *et seq* . The lead and copper regulations use the term "action level" for each substance, for purposes of regulatory compliance. These action levels should not be confused with DHS'

advisory action levels for unregulated chemical contaminants

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Action levels for copper and lead, which are to be met at customer tap, are used to determine the treatment requirements that a water system is required to complete. The action level for copper is exceeded if the concentration of copper in more than 10 percent of tap water samples collected during any monitoring period conducted in accordance with 22 CCR §64682-§64685 is greater than 1.3 mg/L. Similarly, the action level for lead is exceeded if the concentration of lead in more than 10 percent of tap water samples collected in accordance with 22 CCR §64682-§64685 is greater than 0.015 mg/L. Failure to comply with the applicable requirements for lead and copper (22 CCR Chapter 17.5) is a violation of primary drinking water standards for these substances.

APPENDIX E

Data Management Plan

APPENDIX E
DATA MANAGEMENT PLAN

1.0 MANAGEMENT

During the Project, a large amount of data will be generated. The purpose of this data management plan is to establish guidance for data filing, storage, and security during the Project and after Project completion. Data will be filed and stored in both a Project file and in a computer database.

2.0 PROJECT FILES

Project files that store all technical project documents will be established. Technical documents include, but are not limited to, the following:

- All correspondence to/from regulatory agencies,
- Memoranda containing technical information or documentation of technical decisions,
- Reports,
- Field data sheets,
- Field logs/daily reports,
- Laboratory reports,
- Computer files of technical data,

- Minutes of meetings with regulatory agencies,
- Permits,
- Legal documents,
- Press clippings,
- Fact sheets,
- Photographs,
- Calculations,
- Quality assurance/quality control (QA/QC) reports.

Information regarding each document will be entered into a computer database and the document filed in the Technical Project File.

2.1 Storage and Security

Active Project files will be maintained at a place to be designated by Metropolitan while the Project is ongoing. Technical Project records will be stored and secured in locking file cabinets. Prior to storage, records will be assigned a sequential number and entered into the project reference database. The database will include the following items of information for each document to assist in retrieval:

- Document number,
- Date document was generated or received,
- Type of document,
- Author and corporation,
- Addressee,
- Subject (description of document contents),
- Source of document, and
- Project/Task No. (and associated task description).

2.2 File Access

Once placed in the Technical Project File, records will be checked out by placing a checkout card in the file in place of the project record. Access will be limited to Metropolitan's technical experts, Metropolitan personnel and/or their legal representative, Cadiz, Inc. personnel, and agency representatives. Personnel who are not directly involved with the project may obtain access to project files only after receiving approval from the Project Manager or a designated project representative.

2.3 File Closure

At the close of the Project, files will be closed and transferred to Metropolitan.

3.0 PROJECT DATABASE

Data also will be stored, organized, and secured in a computer database created specifically for the project. The database will store data in an efficient and usable manner.

Types of data to be sorted in the computer database may include, but are not limited to, technical information such as results of groundwater analytical records, well construction details, and water levels. Project tracking records, such as schedules and records management data, also will be most effectively organized using a computer database and related programs. Storage and organization of project tracking records will follow guidelines outlined in this section.

Technical and database programs used during the Project will be those designed to run on IBM-compatible computers. If programs designed for other operating systems are used, the data files will be transferable to an IBM-compatible format.

Access, Paradox or other equivalent relational database software will be used for general database applications. Specific technical programs used for data analysis will be selected based on the specific technical question to be answered.

3.1 Database Construction

The database construction process will consist of three phases: design, implementation, and testing. The database will be designed to meet the output requirements of the dataset and will be structured to avoid redundant input of information by separating data into separate files when possible. Data items will be coded when possible and standard naming conventions for similar data items will be used.

Databases will be implemented using software that is best suited for storage and manipulation of the data to meet the output requirements. Once the physical construction of the database has been completed, a sample set of data will be input and thorough testing will be performed to ensure that the required output can be achieved.

3.2 Maintenance

Databases created for a specific task will be maintained by the Database Manager. This individual will be responsible for the creation, implementation, testing, documentation, and security of the database. The Database Manager will ensure that data entered into the database is complete and correct.

The Database Manager also will coordinate the many individual databases created for the investigation so that the database design is appropriate and the data are represented in a consistent manner according to standard formats. The Database Manager will provide a central storage location for data files and documentation.

3.3 Documentation

Documentation will be prepared regarding the database files and file structure, QC of data entry, and analysis and manipulation of the data. The objective of documentation is to provide enough information for individuals unfamiliar with the data to work efficiently within the database. It also will provide a clear work history to simplify data reconstruction, if necessary. Documentation records will be submitted to the Database Manager for permanent storage when the database is complete.

File documentation will include a complete description of database fields and types. Codes will be listed with an explanation of the data they summarize. The relationship between files will also be included. A list of files using the described structures and including the date of creation, number of records, and sources of data will be provided as a part of the file documentation.

Data entered manually (typed in) will be printed out and compared to the source document. The printout will be initialed and dated when the QC review is performed and when corrections are made to the data file. If data are imported from other sources, randomly chosen records will be compared to the source file. If discrepancies occur, the entire importing process will be reviewed, corrected, and re-executed. If no discrepancies occur, a document will be submitted listing the date of the comparison, which file was checked, and the individual who performed the QC review.

3.4 Security

Proper back-up and security measures will be taken to prevent accidental loss of data and tampering with the database. Exact duplicates of working files will be made at least once each work session. The backup files will be stored in a separate physical location from the working files. Both the backup and working files will be kept in a locked storage area.

If the software program used offers data protection through passwords, passwords will be used for working and backup files. The password protection will be removed when files are submitted for permanent storage.